Patent Application

1. Introduction

This document describes the algorisms to support the WLAN 802.11b enhancement ASIC 11b[e] and its functional blocks. 11b[e] intends to be used in the WLAN 802.11b access point with multiple antenna, RF receivers and transmitters. 11b[e] serves as a scalable signal processing engine for all functions of range and speed enhancement in the WLAN 802.11b physical layer. The hardware and software changes for the enhancement are only limited in the access point. The mobile unit will be a standard 802.11b device.

The focus in the following sections will be on the general principles of the system, the system aspects of the design describing the functionality that needs to be provided by the chip and then defining the internal blocks within the chip that implement a particular functionality. Therefore, this document should serve as a reference for the architecture of the chip within a complete system.

A complementary document to the present one will include the signal level description of the blocks within 11b[e]. The detailed documentation of all internal signals of the chip will be compiled as part of the implementation process.

2. 11b^{e} Operation Principles

802.11b^{e} ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be understood as a Multi Inputs Multi Output (MIMO) system or Single Input Multi Output (SIMO) system. Its principle of operation will show as following:

$$Y = AX + N \qquad (1.0)$$

where $\mathbf{X} = [x_1(t), x_2(t), \ldots x_N(t)]^T$ is N signals to be transmitted; $\mathbf{Y} = [y_1(t), y_2(t), \ldots y_M(t)]^T$ is M received signals from RF; $\mathbf{A}$ is the M by N propagation medium mixing matrix; $\mathbf{N} = [n_1(t), n_2(t), \ldots n_M(t)]^T$ is M additive white noises from M receivers. In the time domain, Eq. 1.0 can be considered as either multi-path delays are short or does not exist. Our existing analog signal separation demonstration is the implementation under such situation. When those conditions that multi-path delays are small cannot be met, **AX** in Eq. 1.0 either can be considered as convolution operation or it is in the frequency domain. Usually the convolution operations are complicated, we will concentrate our effort in the frequency domain cases.

The least squares solution to Eq. 1.0 is:

$$X = (A^*A)^{-1} A^*Y \qquad (1.1)$$

Where the channel mixing matrix **A** can be either blindly estimated as what was done in the analog implementation using HJ networks with Bartley matrix, or using the training signal which is the preamble of the Physical Layer Convergence Protocol (PLCP) in 820.11b.

The performance enhancement of the multi-antenna (SIMO) Access Point (AP) is benefited from two aspects:

1). The transmitted and received power is M times larger than the traditional single transmitter-single receiver (SISO) AP. When the noise mainly coming from the multipath delays, the enhancement provides a very good way of equalization for the multipath. The signals after equalization will be at least M times strong than the single receiver system. If $M = 4$, the increase in the received power will be translated to 2x range increase, since

$$P = M*p_0*(2*r)^{-2} = p_0*r^{-2} \quad (1.2)$$

Where P is the power received by $M = 4$ receivers, p_0 is the power received at an unit distance from the radiator.

2). When the multipath delays are long enough, the multipath effect can produce a frequency selective fading. The frequency selective fading effect means that the received signal $S(t)$ at frequency f_1 — $s_1(t)$ is much weaker than the received signal $S(t)$ at frequency f_2 — $s_2(t)$. The effect can be illustrated as following:

$$s_1(t) = e^{-i2\pi f1t} + e^{-i2\pi f1(t+\Delta t)} = e^{-i2\pi f1t}(1 + e^{-i2\pi f1\Delta t}) \quad (1.3a)$$

$$s_2(t) = e^{-i2\pi f2t} + e^{-i2\pi f2(t+\Delta t)} = e^{-i2\pi f2t}(1 + e^{-i2\pi f2\Delta t}) \quad (1.3b)$$

where $S(t)$ is the resulted signal from the combination of the two paths, $s_1(t)$ and $s_2(t)$ are the frequency components of the signal $S(t)$ at frequency f_1, frequency f_2, respectively. In (1.3a) and (1.3b), the two paths are assumed to have the same amplitude but with a delay difference Δt. To see the frequency selective fading effect, one can let $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$, which translates (1.3a) and (1.3b) to:

$$(1 + e^{-i2\pi f1\Delta t}) = 0 \quad (1.3c)$$

$$(1 + e^{-i2\pi f2\Delta t}) = 2 \quad (1.3c)$$

For the smallest possible Δt to produce the effect of $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$

$$f_1\Delta t = 1/2 \quad (1.3e)$$

$$f_2\Delta t = 1 \quad (1.3f)$$

Therefore

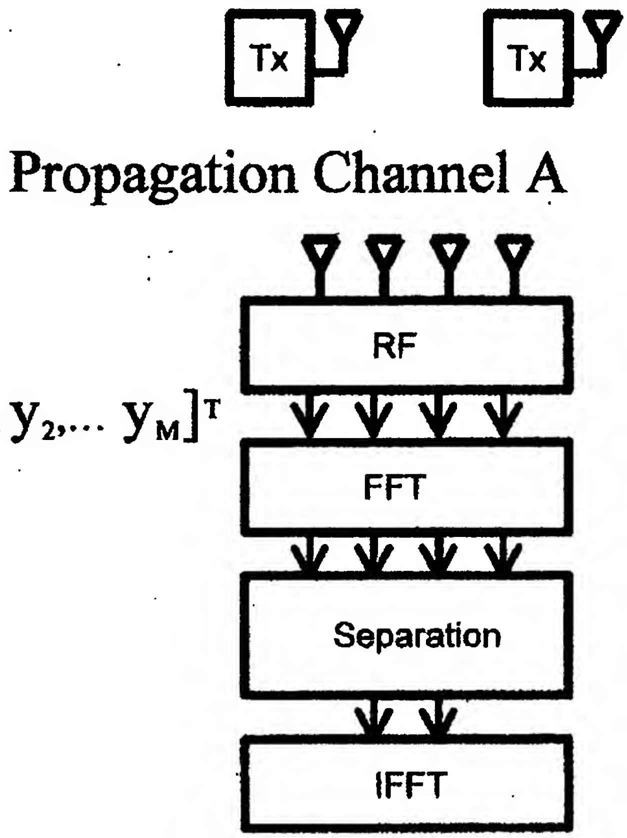
$$(f_2 - f_1) = 1/(2\Delta t) \quad (1.3g)$$

In the 802.11b system, the bandwidth is 22MHz. If f_2 and f_1 are two frequency points in the band, one can see for $f_2 - f_1 = 11MHz$, $\Delta t = 46ns$. That means the delay as small as 46ns, at some favorite conditions can produce a severe frequency selective fading. The delay difference of 46ns can be translated a path difference 14 meters, which can be easily seen in SOHO environments. When the wireless device bandwidth increases for the none 802.11 applications, the path difference will decrease and to be seen even easer.

When the frequency selective fading happens, the performance of the multi-antenna AP is much better than that of the traditional single transmitter-single receiver AP. The traditional AP deals the frequency selective fading with an equalizer. However, as shown in (1.3c), the signal component $S_1(t)$ at frequency f_1 is zero and therefore there is no signal to equalize with. The traditional AP only has two options: either switch to the low data rate mode and using the processing gain to compensate the frequency null, or switch to the other antenna. The trade off of the former option is a slow data rate. The later option does not have the guaranty of absence of the frequency selective fading at the different frequency f_i for the other antenna. At the same time the traditional AP does not take the advantage of the fact that we have a very good reception at frequency f_2.

When the frequency selective fading happens, the multi-antenna AP uses (1.1) to compensate any frequency null from the information from the other antenna automatically, and provides an optimum solution for the reception.

Fig 1 shows the signal processing structure to realize the algorithm above. Fig 2 shows a possible ASIC implementation of the signal processing structure. This chip can realize an added-on scalable architecture through multi-transceiver.



$$\mathbf{Y} = [y_1, y_2, \ldots\ y_M]^T$$

$$\mathbf{X} = [x_1, x_2, \ldots\ x_N]^T$$

Fig. 1
Principle of Spatial Separation

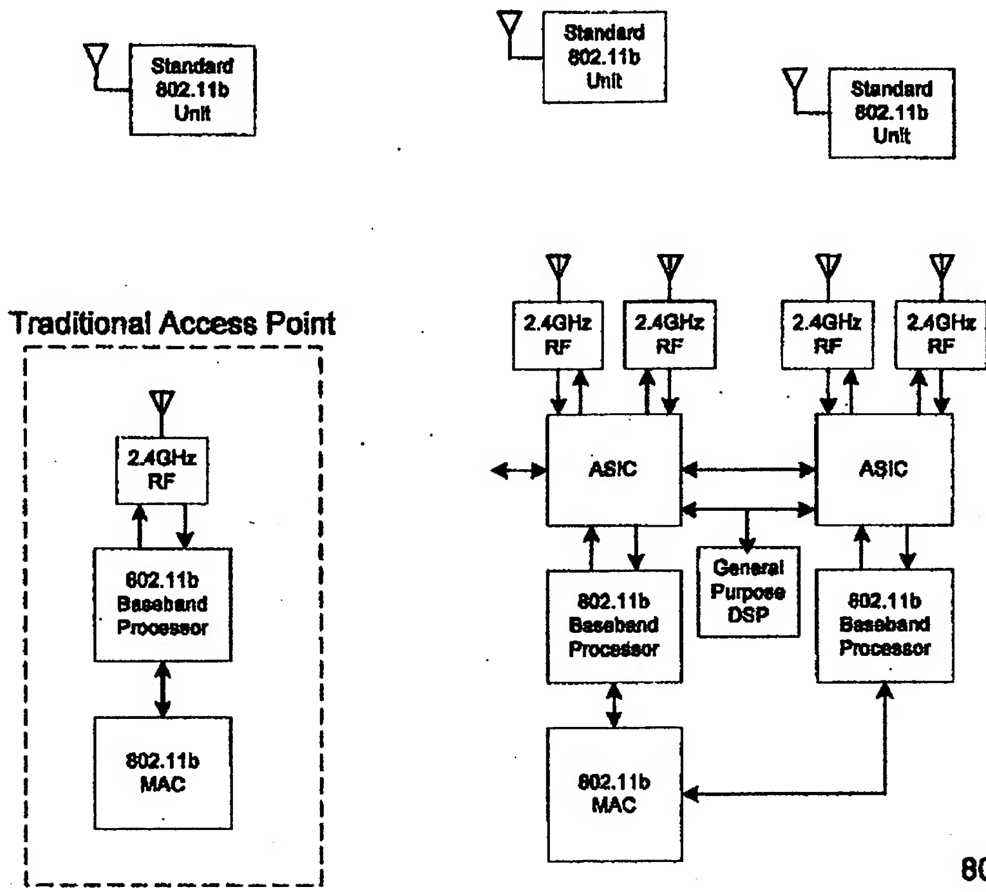


Fig. 2
Configuration for
802.11b enhancement

The 802.11b WLAN Access Point enhancement ASIC can dramatically increase the performance of the 802.11b system. The though-put of 802.11b system under various propagation conditions is shown in Fig. 1. The green area in Fig.1 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 1.

3. 11b[e] ASIC Blocks, Interfaces and Their Functionality

The internal block diagram of 11b[e] ASIC is shown in Figure 5. 11b[e] ASIC consists of the following major functional blocks and interfaces:

- Clock Generator
- SDRAM Buffer Interface Address Generator
- Three 1024-point FFT/IFFT switch able blocks
- Separation Matrix Multiplier
- On Chip Parameter Memory Bank
- Inter-chip Data Exchange Interface
- DSP Interface
- Preamble Acquisition Module
- Four 6bit A/D at 22MHz
- Four 8bit D/A at 44MHz

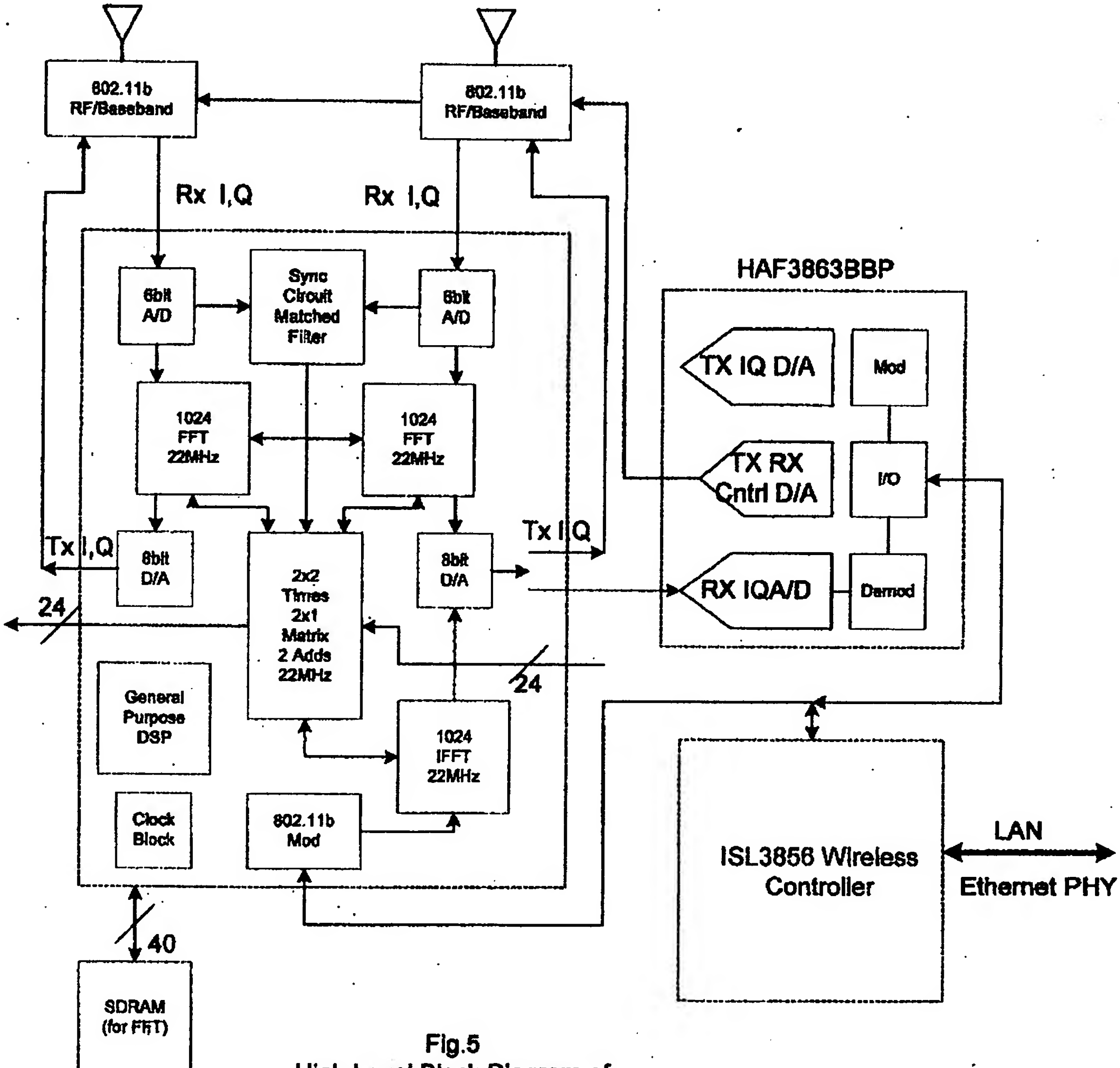


Fig.5
High Level Block Diagram of
11b* ASIC

3.1 Clock Generator

This module provides all necessary clocks and control signals for other modules of 11b[e]. The key features of this module are described below.

3.1.1 FFT and IFFT Module Clock

The clock generator provides FFT/IFFT modules for the system clock of FFT operation. The system clock cycles for each FFT frame are calculated as the following:

number of passes = ceiling[($\log_2$points)/2]

= 5

number of clock cycles per pass = 14 + points + ceiling[$\log_2$(twiddlewidth)]

= 14 + 1024 + 4 = 1042

number of clock cycles per frame = number of passes * number of clock cycles per pass

= 5210

The minimum clock speed for the FFT/IFFT module with 18% safety margin is:

Clock Rate = 5210/1024*22MHz*118% = 132MHz

The clock rate 132MHz is 3 multiple of the basic clock rate 44MHz. The clock rate 132MHz is generated by using PLL to locked on the system clock 44MHz. The interactions and coordination between the FFT Input SDRAM Buffer and FFT modules is done through a third sub-module, the Arbiter.

3.1.2 FFT Start Frame Timing Control

The FFT start frame timing control signal is provided by the Preamble Acquisition Module. This signal indicates the start data position pointer in FFT Input SDRAM Buffer.

3.1.3 Separation Multiplier Start Timing Control

The clock generator module also provides Separation Multiplier Start Timing Control.

3.2 SDRAM Buffer Interface Address Generator

The interface either uses a general purpose DSP or a configurable interface logic. It still is an open question.

3.3 1024-point FFT/IFFT switch able blocks

There are three 1024-point FFT blocks operating at 130MHz system clock. The blocks can be switched between FFT and IFFT. The input real and imaginary data are 8 bit.

3.4 Separation Matrix Multiplier

This module essentially perform the following operation at 22MHz when is in receiving mode

$$x = b_1 * y_1 + b_2 * y_2 + x_0$$

where b_1 and b_2 are calculated equalization coefficients; x_0 is the adjacent ASIC recovered signal; y_1 and y_2 are two received data from the current ASIC two baseband channels; x is the recovered signal. All of them are complex numbers. The operations are 2 complex multiplications and 2 complex additions. The resolution of b_1, b_2, x_0, y_1, y_2, x are 12 bits.

This module perform the following operation at 22MHz when is in transmitting mode

$$T_1 = b_1 * x_t, \qquad T_2 = b_2 * x_t,$$

where b_1 and b_2 are calculated pre-equalization coefficients; x_t is the to-be transmitted signal; T_1 and T_2 are two baseband signals to responding antenna;

3.5 On Chip Parameter Memory Bank

The coefficients b_1, b_2 are the estimated channel equalization parameters for a particular 802.11b station. The on-chip parameter memory bank holds 2*1024 complex parameters for

each 802.11b station. If there are 10 such stations to handle, the size of memory bank is 2*2*1024*12*10 = 491520 bits. The on-chip parameter memory bank is supposed to be SRAM.

3.6 Inter-chip Data Exchange Interface

The interface is designed to transfer the data y_0 from the adjacent ASIC and to transfer y_0 the next ASIC.

3.7 DSP Interface

The DSP interface will depends on the general purpose DSP we have chosen.

3.8 Preamble Acquisition Module

The acquisition block performs the initial preamble PN code timing acquisition in the receiver. The processing in this block is based on performing a set of matched filtering operations. This approach is adopted primarily to provide a fast acquisition mechanism.

The matched filtering operation is performed by four 16 chip matched filters, providing a filter that is matched to any 64 chip complex sequence. The input to the matched filter is the stream of received samples at twice the chip rate. Thus, the timing accuracy provided by the Acquisition block is of the order of ¼ of a chip duration.

4. Operating Procedures

This section describes some of the system operation procedures that rely on explicit support from 11b. More specifically, the portion of system operations that deals with the physical layer aspect of preamble acquisition and connection enhancement are described below.

4.1 Operation Philosophy

The intention of 802.11b WLAN Access Point enhancement is to realize an added-on scalable architecture through multi-transceiver to dramatically increase the performance of the 802.11b system. The projected though-put of 802.11b system under various propagation conditions is shown in Fig. 8. The green area in Fig.8 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 8. The enhanced receiver portion and the standard receiver will operate simultaneously. When a STA is the green, the communication between AP and STA through the standard 802.11b chip set as long as the AP satisfies with the link through-put. Whenever the STA in the red area or in low data rate green area due to the poor reception or the distance from AP, the enhancement portion can kick in, estimate the channel using the frame of data which the standard 802.11b chip set can not decode on, transfer the data mainly under the mode **point coordination function (PCF).**

The PCF provides contention-free frame transfer. The PC shall reside in the AP. It is an option for an AP to be able to become the PC. All STAs inherently obey the medium access rules of the PCF, because these rules are based on the DCF, and they set their NAV at the beginning of each CFP. The operating characteristics of the PCF are such that all STAs are able to operate properly in the presence of a BSS in which a PC is operating, and, if associated with a point-coordinated BSS, are able to receive all frames sent under PCF control. It is also an option for a STA to be able to respond to a contention-free poll (CF-Poll) received from a PC. A STA that is able to respond to CF-Polls is referred to as being CF-Pollable, and may request to be polled by an active PC. CF-Pollable STAs and the PC do not use RTS/CTS in the CFP. When polled by the PC, a CF-Pollable STA may transmit only one MPDU, which can be to any destination (not just to the PC), and may "piggyback" the acknowledgment of a frame received from the PC using particular data frame subtypes for this transmission. If the data frame is not in turn acknowledged, the CF-Pollable STA shall not retransmit the frame unless it is polled again by the PC, or it decides to retransmit during the CP. If the addressed recipient of a CF transmission is not CF-Pollable, that STA acknowledges the transmission using the DCF acknowl-edgment rules, and the PC retains control of the medium. A PC may use contention-free frame transfer solely for delivery of frames to STAs, and never to poll non-CF-Pollable STAs.

4.2 Cycle Stealing

An 802.11b transceiver with WLAN Enhanced ASIC between the 11b baseband processor and the RFE. Since an average of 50uS is introduced in the RX data path, a special "cycle-stealing" concept has been applied to avoid the violation of IEEE 802.11

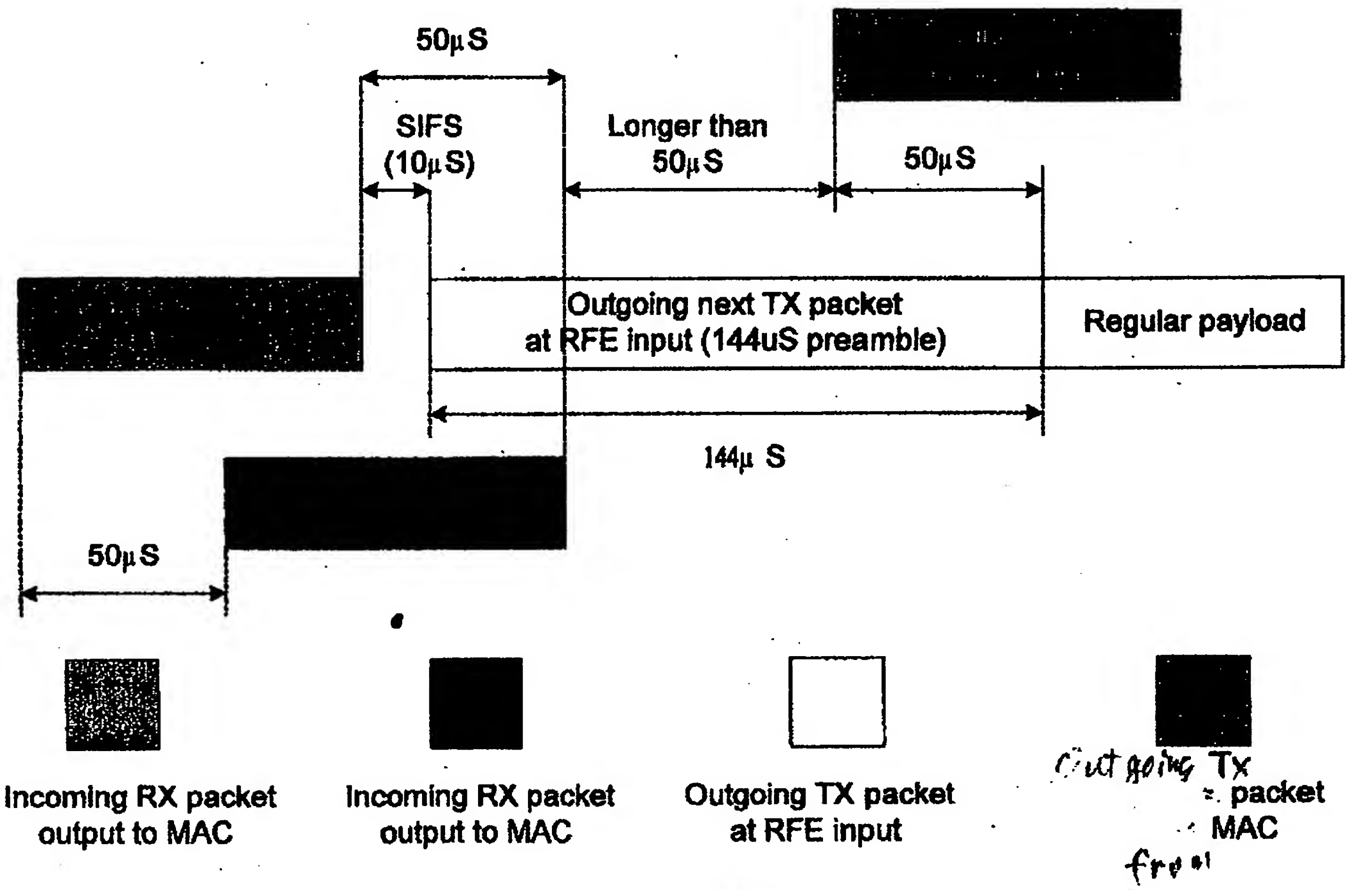


Fig. 9
Cycle-stealing Mechanism

SIFS or PIFS timing.

As shown in , SIFS(10uS) after the end of previous RX packet, a pre-stored 144us preamble is issued before the previous RX packet is fully decoded. Therefore the 802.11 SIFS timing can be maintained.

4.3 Preamble Acquisition

Preamble acquisition is performed by the ASIC to line up the FFT frame with the incoming data stream. After the preamble acquisition, the FFT frame in the SYNC of the preamble will provide the channel estimation of the following separation and combining.

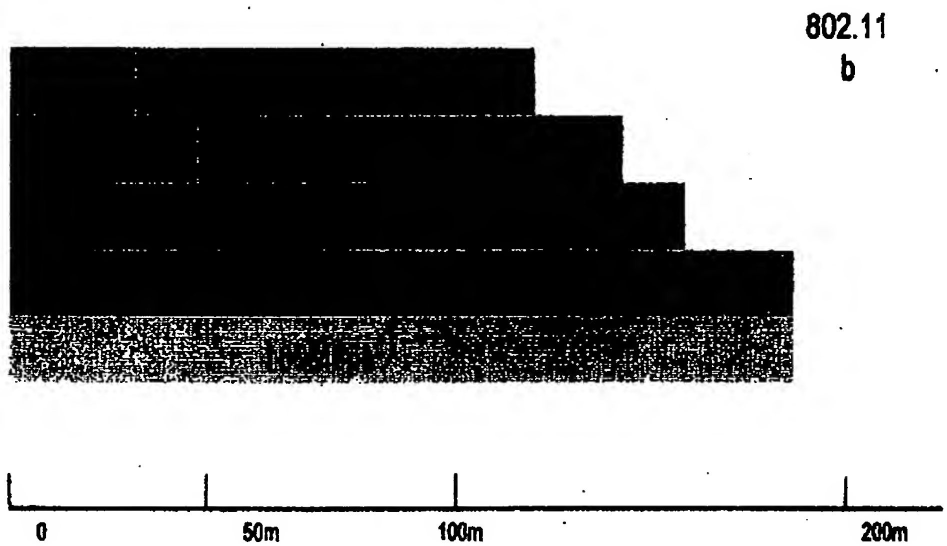


Fig. 10
802.11b enhancement

5. Claims

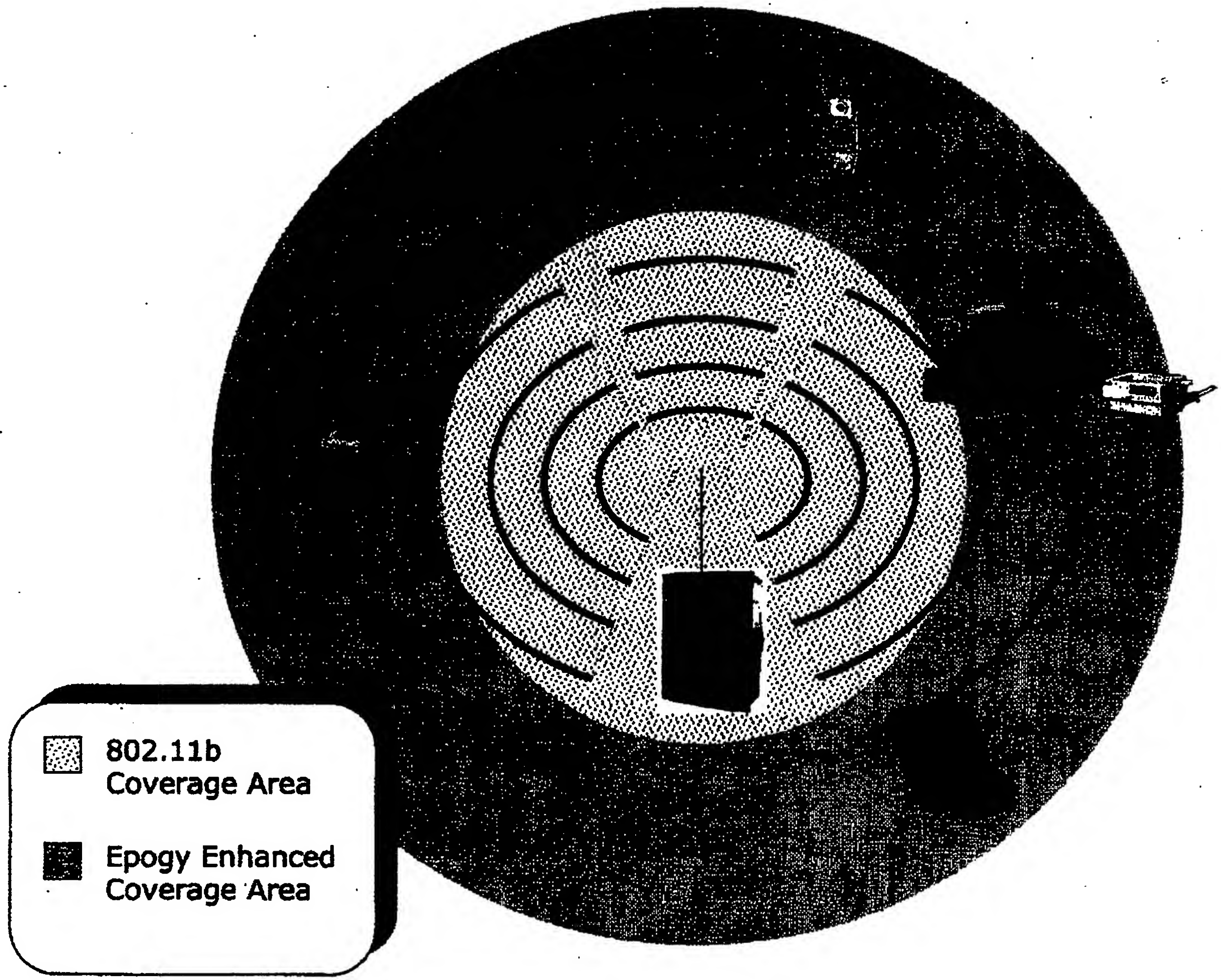
1. Apply MIMO technique to WLAN such as 802.11b and 11a, significantly enhance the performance of 802.11b Access Point in high speed mode in long range. The enhancement can be seen in Fig.10.

2. Combination of RF signals in a unique way to handle the case when the separation angle of incoming signals is small.

3. Separate different RF signals from different directions simultaneously, effectively realize Space Division Multiple Access (SDMA).

4. Cycle stealing eliminates the impact of processing time delay in the signal combining unit to 802.11b MAC.

5. Can be integrated in a CMOS chip with the 802.11b or 11a baseband processor.


802.11b
Coverage Area
Epogy Enhanced
Coverage Area

Location Encryption

epogy
communications

Multi-Antenna Technology for 802.11 WLANs

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communications

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Executive Summary

Today, people seek out information on the Internet. And tomorrow, information will seek out people using the Internet. One of the enabling technologies for this is a global wireless connection starting with a wireless local area network (WLAN). Historically, the WLANs were viewed as a niche market with proprietary protocols, high costs, and unrealized performance. With the adoption of IEEE 802.11 standards, WLANs now offer a viable alternative to wired LANs, as evident with the explosive growth over the past year. Both large and small companies have or plan to offer solutions based on IEEE 802.11b (WiFi™), 802.11a and 802.11g. For wide spread adoption, issues in the form of security, higher speeds, and increased radius of operation will need to be addressed. In this paper, Epogy Communications, Inc. describes a new scalable technology, ($11b^e$), utilizing multiple antennas. What distinguishes this technology from other multi-antenna techniques is the simultaneous utilization of all the antennas for transmission rather than selecting the best one antenna. The result is a dramatic improvement in both performance and security. The technology is capable of supporting IEEE 802.11 standards and extends the higher speed range by 10X. Used in conjunction by the access point and mobile terminal, the $11b^e$ technology would enable users to achieve speeds greater than 100 Mbps. However, the main feature of $11b^e$ is the ability to provide security beyond encryption through energy modulation. This new technology provides enhanced security depending on the adopter's preference by not only encrypting the data but by concentrating and selectively reducing the energy so that the transmitted data is indistinguishable from noise.

WLAN Overview

Today's Internet is very different than what it was before; we now view the Internet as a utility, which distributes the flow of information. Much like the water or electric utilities, the Internet is available in almost every school, home and office. It is the fastest growing global information and communications medium with connections available most anywhere. Today people seek out information on the Internet. And tomorrow information will seek out people using the Internet. How will this information reach you, without you having to reach it? The Internet will become wireless, and information will reach you via your cell phone, PDA or laptop. One of the enabling technologies for this global wireless electronic blanket is wireless Ethernet, specified by the Institute of Electronics and Electrical Engineering (IEEE).

Wireless local area network (WLAN) is a communications system that either replaces traditional wired LAN or extends its access beyond the limitations of physical wires. Historically, WLAN was viewed as a niche market for specialized applications like inventory or shipment tracking. Users were limited in throughput, radius, or interoperability with wired LANs due to proprietary protocols.

The adoption of 802.11 standards made possible increased speeds, interoperability between systems, and cost reductions that made WLAN a feasible alternative. Companies like Lucent, Intersil, Cisco, 3COM, Texas Instruments, Microsoft, and Intel have or have announced products supporting the IEEE 802.11 standards. The 802.11 standards define the physical layer (PHY) and media access control layer (MAC); since these layers are based on 802 Ethernet protocol and CSMA/CA shared media techniques, any LAN application, network operating system, or protocol (such as TCP/IP) will run on a 802.11 compliant WLAN.

The WLAN market is comprised of several technologies all competing with different techniques and performance characteristics.

- HomeRF and Home Rf 2.0 (WBFH)
- IEEE 802.11b (DSSS)
- IEEE 802.11a (OFDM)
- IEEE 802.11g
- HiperLAN/2
- MMAC

At the moment, the focus of the standard is on ether the 2.4 GHz band known as 802.11b or the 5 GHz band known as 802.11a. The supported data rates are up to 11 Mbps for 802.11b and are up to 54 Mbps for 802.11a. Products which conform to the 802.11b spec will in most cases work together and interoperate with ease. Essentially, the 802.11b or 11a standard provides open, asynchronous networking that requires a distributed control function.

Much like base stations for cellular technology, WLANs use the Access Point (AP) to provide wireless access to mobile terminals (MTs) or other devices in the network. AP is

a cheap version of the base station for cellular technology and plays a very important role in WLAN. These APs are either connected to other APs, to other wired networks such as Ethernet, or connected to a broadband access medium such as DSL, cable, T1, etc.

IEEE 802.11b

The IEEE 802.11b operates in the unlicensed 2.4 GHz band. This standard permits two (2) distinctive types of transmission for data, Frequency Hopping Spread Spectrum (FHSS) and Direct Sequencing Spread Spectrum (DSSS). With the number of products and companies supporting DSSS, it has become the predominate standard for IEEE 802.11b. A raw data rate of 11 Mbps, 5.5 Mbps, 2 Mbps, or 1 Mbps is specified with a range of 100 meters.

Conventional configurations include single carrier, single receiver (Rx) and single transmitter (Tx) deploying a single omni-directional or dual dipole antenna. This is a simple and low cost solution.

802.11b is the predominate solution available on the market today. Since lower cost RF components may be used to achieve the requirements of 802.11b, the system cost has contributed to rapid growth.

Fundamental wireless channel impairments such as multipath (delay spread, temporal and frequency fading), interference, and noise greatly reduce the radius of the system. In most indoor environments, the 11 Mbps data rate is not achievable at 50 meters.

IEEE 802.11a

For higher speeds, companies are looking at IEEE 802.11a with 54 Mbps data rate. 802.11a uses a technique called Orthogonal Frequency Division Multiplexing (OFDM). OFDM sends multiple data streams simultaneously over separate radio signals in the less congested 5 GHz radio band, which has three (3) times the available spectrum. However, as the number of devices utilizing this band increases, congestion will also become an issue.

Although 802.11a offers a high data rate of 54 Mbps, a fundamental difference between 2.4 GHz and 5Ghz is the transmission range and corresponding coverage area. All things being equal, a higher frequency band will transmit a signal a shorter distance than a lower frequency band. The actual range at 54 Mbps in many instances may be less than 20 meters. This is of particular significance when considering the number of access points (APs) required for a similar area of coverage using 802.11a compared to 802.11b. Figure 1 shows the data rates and their typical coverage range for 802.11b and 802.11a.

Generally speaking, as the noise and interference increases the decipherable signal radius decreases. As a result, additional APs are required to complete coverage for a given area increasing costs and contributing to more interference.

Later in the paper, we will describe a multi-antenna approach that reduces those effects of multipath, interference, and noise through a technique called adaptive signal separation processing.

Security

In a recent survey sponsored by Microsoft, security was the primary issue concerning companies implementing WLANs. The 802.11 standards address the issue in a couple of ways: Extended Service Set ID (ESSID) and Wired Equivalent Privacy (WEP). For ESSID, all mobile units associate themselves with an AP. This type of protection is limited since some products allow the mobile unit to attach to any AP, while others allow the user to browse and dynamically attach to a network.

WEP is a shared-key encryption mechanism option under 802.1 that employees either a 40-bit or 128-bit encryption using the RC4 algorithm. Unfortunately, many vendors have only just begun to implement this feature and it still relies on manual key distribution.

Security architectures typically provide a framework for authentication, encryption, message integrity, and key distribution. As this paper will describe, additional security may be possible by modulating the signal's energy level so that the intercepted signal may be undecipherable to noise.

11b^e Enhancements

Security, increased areas of operation (radius) and higher speeds are three (3) of the main barriers facing WLANs. Our mission starts with using the algorithms to enhance the performance of WLAN 802.11b network AP. The enhancement is named as 11b^e, it intends to be used in the WLAN 802.11b AP with multiple antennas, RF receivers and transmitters. 11b^e serves as a scalable signal processing engine for all functions of radius and speed enhancement in the WLAN 802.11b physical layer. The hardware and software changes for the enhancement are only limited in the APs. The mobile terminals will be standard 802.11b devices. With limited modification, the technology can be also applied to WLAN 802.11a and Wireless WAN 802.16.

Operation Principles

The 802.11b^e ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be understood as a Multi Inputs Multi Outputs (MIMO) system or Single Input Multi Outputs (SIMO) system. Figure 2 compares the typical RF reception signal shown as SISO (Single Input Single Output) to that of the enhanced SIMO AP. The curves under these reception methods are the received signal levels and the dashed lines are the would-be designed

sensitivity level of the receivers. We can see the reception is greatly improved by the multi-antenna AP. The theory of the operation may be found in the Appendix.

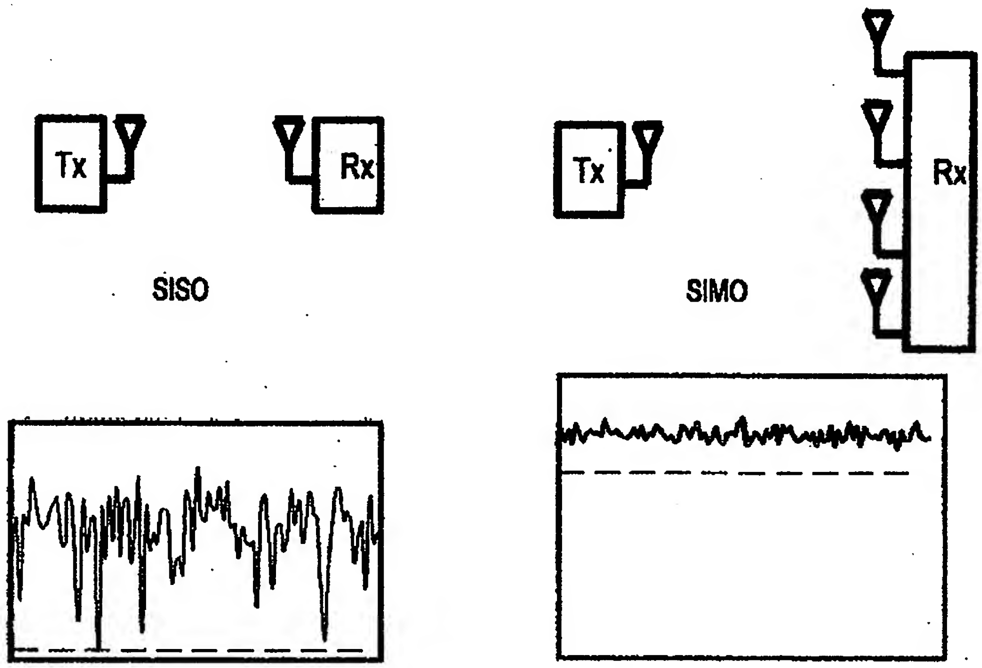


Figure 2:
SISO and SIMO Comparison

Advantages of 11b[e]

In contrast to the traditional AP or multi-antenna AP that receives the signal on the best single antenna, the multi-antenna AP described here optimally combines all energy available from the antenna, equalizes them, and provides the best demodulation possible to decode the signals. This multi-antenna AP has several advantages over the traditional AP.

a. Increasing Covering Radius

The transmitted and received power is M times stronger than that of the traditional single transmitter-single receiver (SISO) AP, where M is the number of antennas. For noise contributed from multipath delays, the enhancement provides a very good method for equalization. The signals after equalization will be at least M times strong than that of the single receiver system. Generally speaking, an M fold-increase of the signal either in transmission or reception would translate to a square root of M fold increase in distance, (see Appendix). Also as shown in the Appendix, the multi-antenna AP automatically compensates any frequency null in the information from the other antenna, and provides an optimum solution for the reception when the frequency selective fading happens.

b. Increasing High Data Rate Covering Radius

The projected though-put of an 802.11b and 802.11a system under various propagation conditions is shown in Figure 3. The green area represents the typical range and data rate of an 802.11b and 802.11a system under such conditions. The performance of 802.11b WLAN AP can be greatly improved through multi-antenna reception as shown by the orange shaded areas in Figure 3. The 802.11b WLAN Access Point enhancement ASIC can dramatically increase the performance of the 802.11b system.

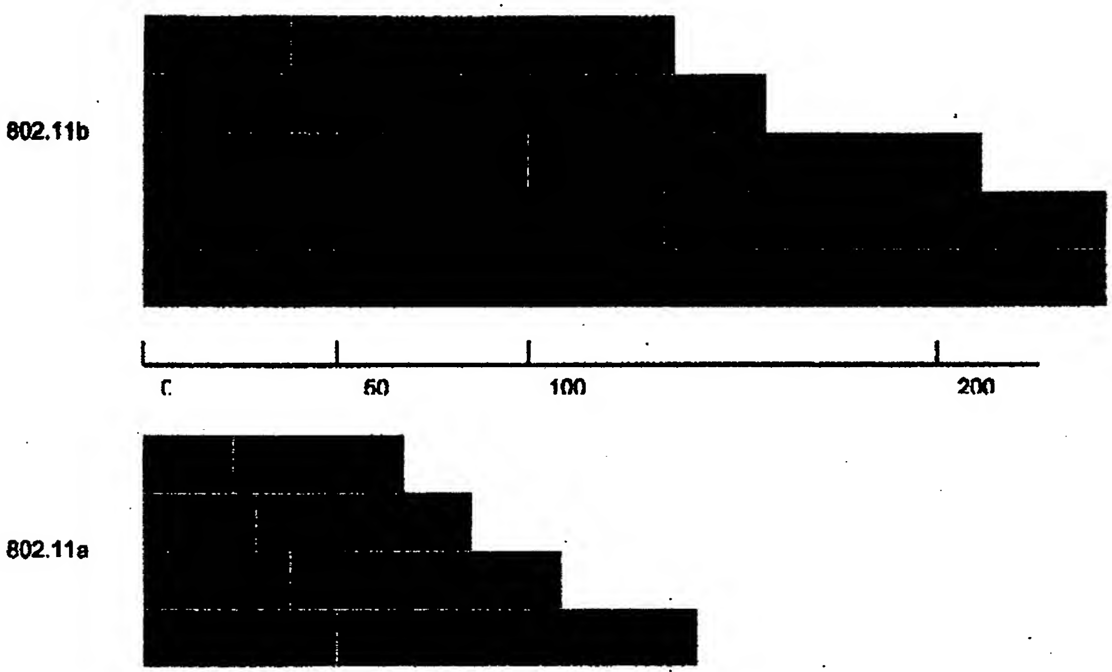


Figure 3:
Performance Enhancement Chart of 802.11b and 802.11a

c. Increasing Security

The emission RF energy from AP is concentrated at the position of the intended mobile terminal (MT), and is significantly less everywhere else. This dramatically decreases the possibility of intercepted by other unwanted intruders.

The RF energy of the signal may be reduced to noise for 95% of the coverage area. Interception would require a device to be positioned similar to the MT; otherwise, the intercepted signal would be undecipherable from noise. This energy modulation security scheme will increase any network's security.

To provide further security, the transmitted data may be encrypted. The encryption scheme used by Epogy utilizes an ever-changing key…________________________.

When used in combination, a total security scheme may be achieved for the transmitted data.

d. A Longer MT's Battery Life

From Figure 2, the multi-antenna AP will experience significantly less fluctuation of the received power as the MT (mobile terminal) moves away from the AP. This would consume less radiated power for the MT to communicate with AP. This will translate to a longer battery life and less interference to the adjacent AP cells.

Architecture of AP Enhancement

The 802.11b WLAN AP enhancement is realized through an added-on scalable multi-transceiver architecture to dramatically increase the performance of the 802.11b system. Figure 4 shows the signal processing structure to realize the algorithm described in the Appendix.

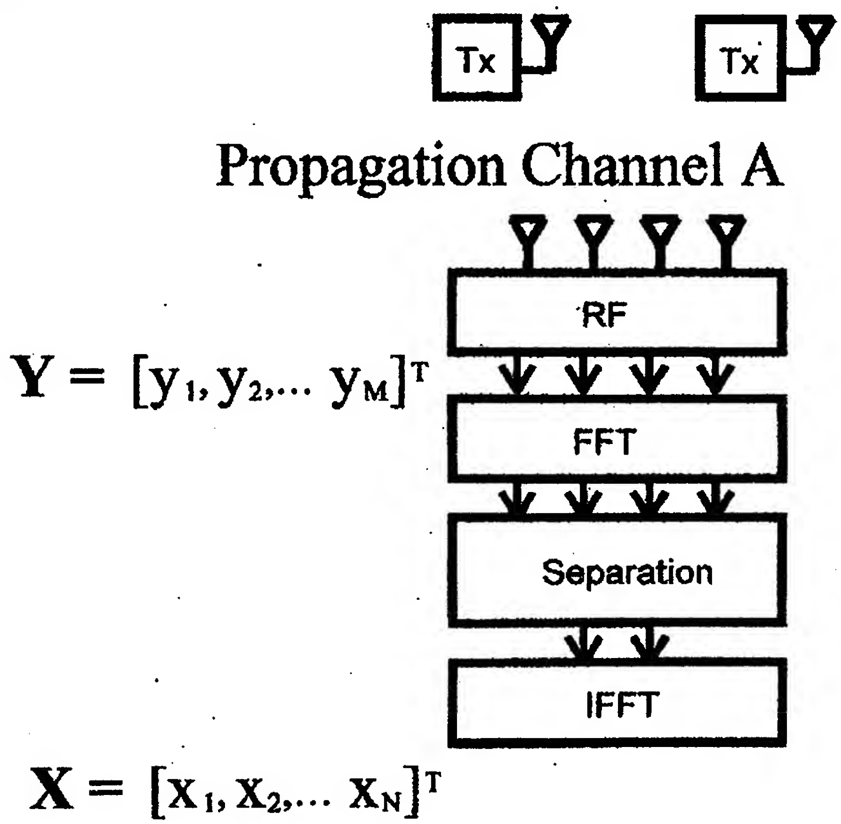


Figure 4:
Spatial Separation Processing Structure

Figure 5 shows a possible ASIC implementation of the signal processing structure. This architecture is flexible should the AP require a higher receiving sensitivity. The number of multi-transceivers can be configured as 2, 4, 6, and so on. The more stages added, the more powerful the AP's performance.

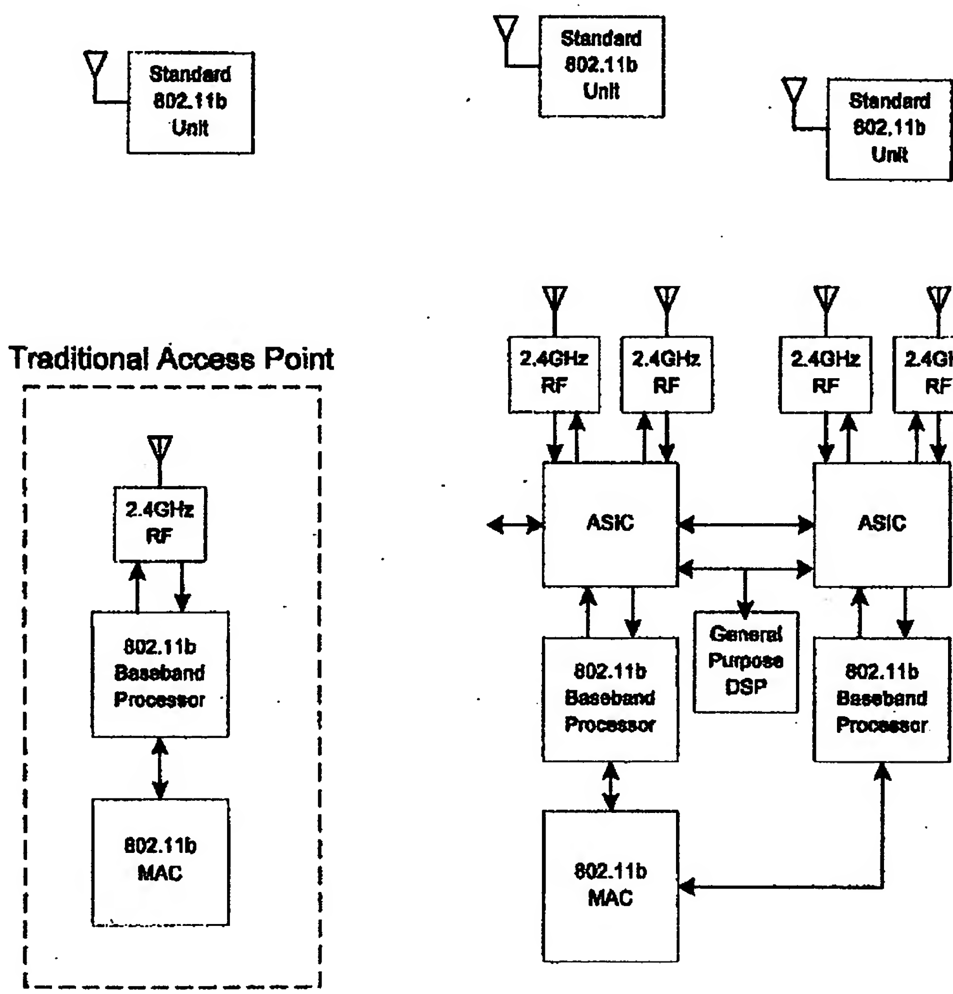
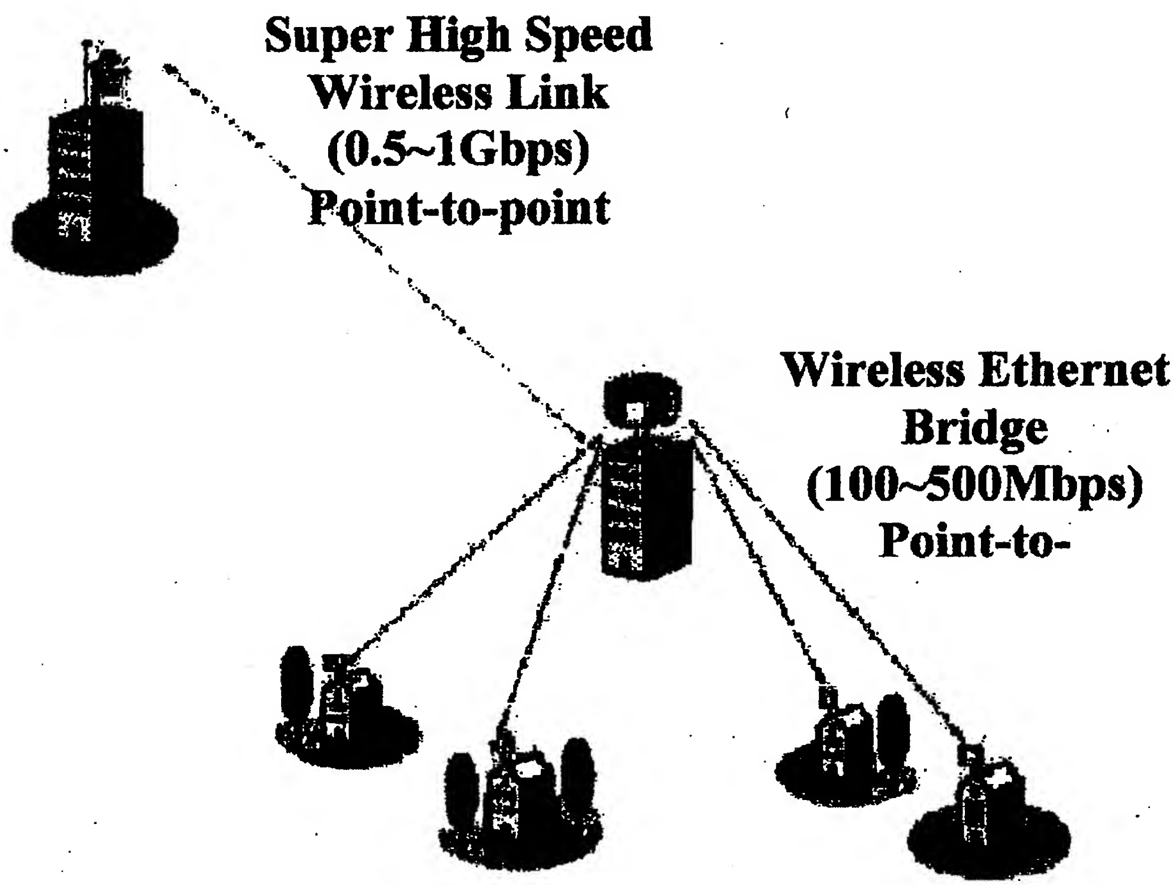


Figure 5:
ASIC Configuration for 802.11b Enhancement

Enhancement Extension

The operation principles of AP enhancement are similar from 802.11b WLAN to 802.16 WAN and 802.11a WLAN. The 802.11b WLAN AP enhancement ASIC can be easily designed to comply with the recently finalized version of 802.16 Wireless WAN. 802.16 Wireless WAN may be considered a wireless solution to the problem of last mile. With some modification, the 802.11b WLAN AP enhancement ASIC can be used for 802.11a WLAN, which seems to be in more of a need for a radius enhancement.



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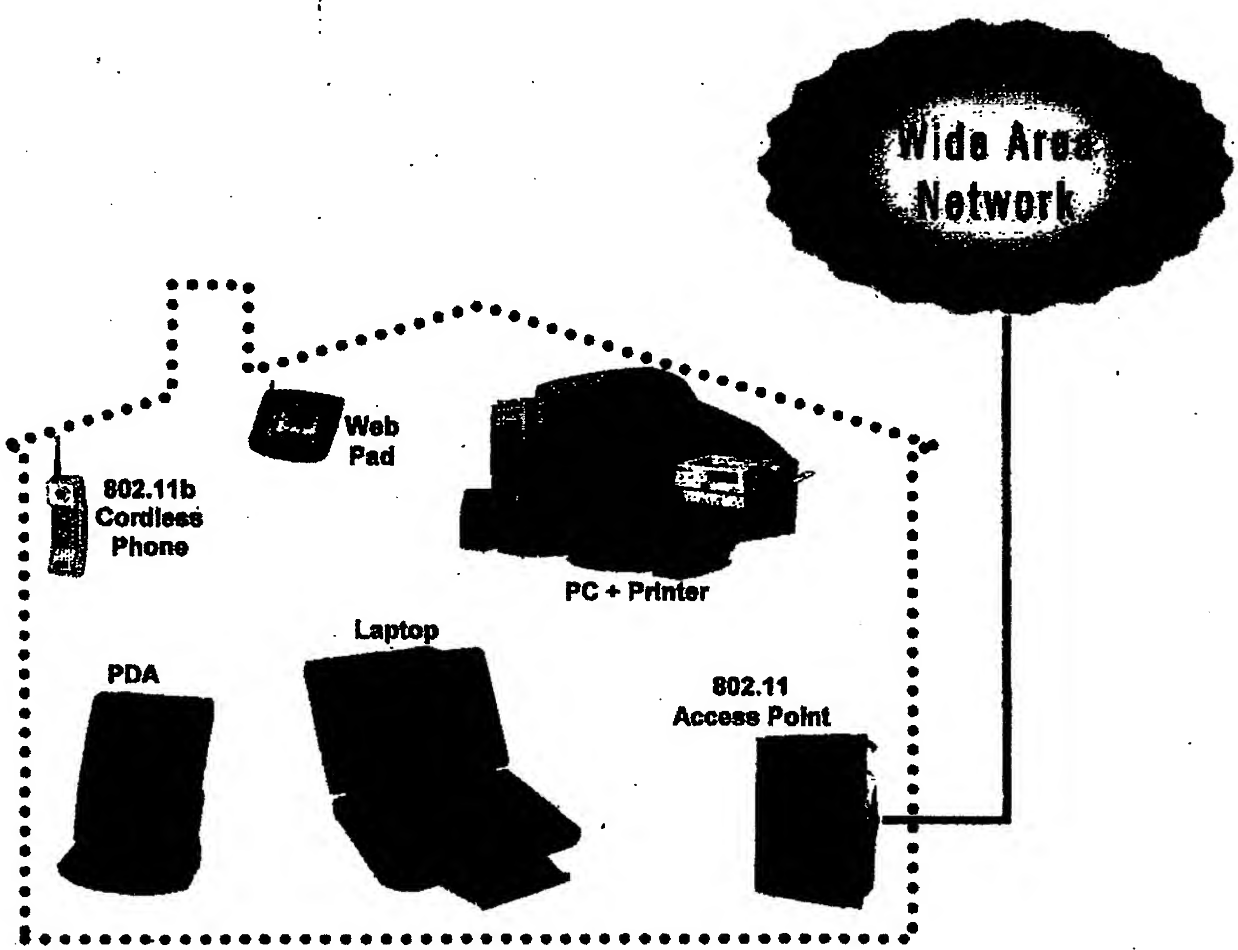
Residential Extension

The residential segment of this market has undergone a revolution with the introduction of the high-speed Internet access into homes. Now more than ever, homes are being networked to support personal computers (PCs), laptop computers, printers, personal data assistants (PDAs), and shared Internet access. The ease of installation and the flexibility to move and relocate a WLAN will see a high percentage of home networking installations go wireless. Many have discussed the possibility of a future convergence to a single access point capable of data, voice, and video.



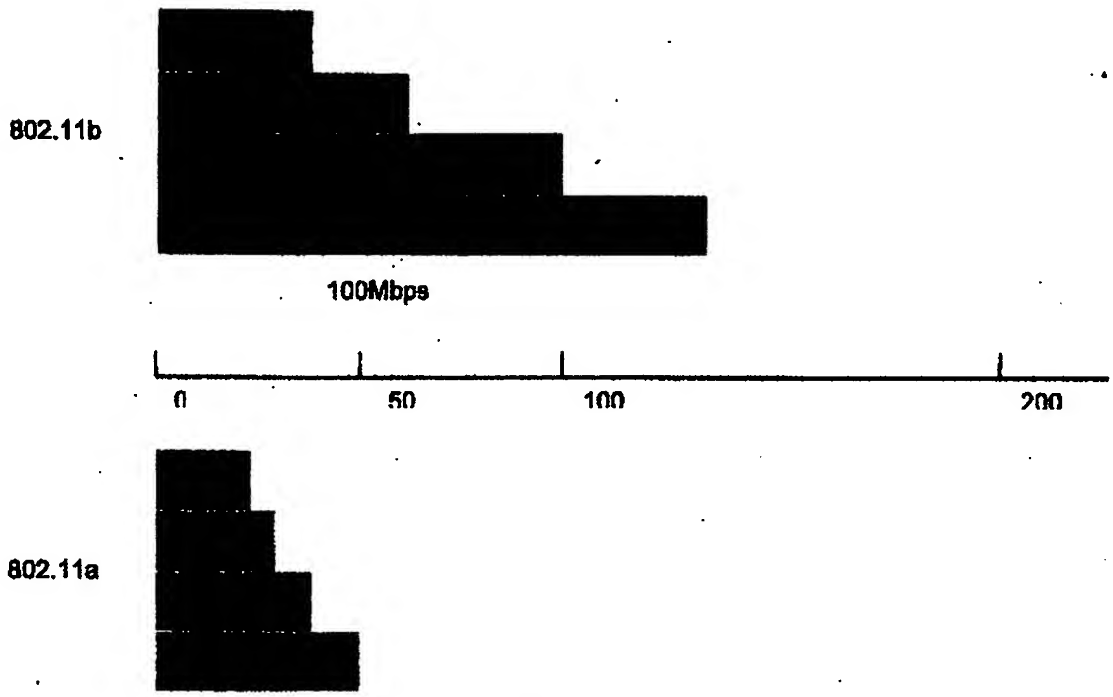


Figure 1:
Performance Comparison Chart of 802.11b and 802.11a

Although numerous companies have announced 802.11a products, only a few have made it to market. Typically, costs are higher due to the more sensitive RF components required. However, costs should decrease as more products make it to market.

Barriers

Interference/Noise

Given the high cost of licensed spectrum, typical WLAN systems utilize either the 2.4 GHz or 5 GHz unlicensed (free) spectrum. As such, other devices and technology like microwave ovens, Bluetooth, satellite systems, and proprietary applications utilizing these unlicensed bands has created an overcrowding situation that will only get worse. A fundamental concern for all WLAN is the interference and noise between devices operating within the same spectrum.

Interference and noise may be viewed in two (2) types; in-band interference and out-of-band interference. Out-of-band interference or noise may be filtered out using the analog section of the receiver. In-band interference would include such time-varying impairments as multiple access interference and multipath conditions. Because the transmitted signal may take multiple paths in reaching the receiver, signal processing is required to address the delay spread, temporal and frequency fading.

Summary

As the Internet continues to revolutionize the information flow, high-speed wireless access will be required to access this information from any location. With an ever-increasing number of devices and users, interference, noise, bandwidth, speed, and security will become the main concerns for WLANs. By using the multi-antenna approach described, WLANs would see a dramatic enhancement in performance and security. In an 802.11b WLAN, the higher speed (11 Mbps) range would be increased ten-fold. When used in conjunction by the AP and MT, speeds in excess of 100 Mbps may be achieved. Even if no additional security or encryption is implemented by the WLAN, by concentrating the RF energy at the MT's position, the transmitted signal would appear to be noise and virtually undecipherable everywhere else. The technology is scalable depending on its specific needs. Although the technology presented in this paper offers a new technique in addressing WLAN issues, it may be implemented for any form of wireless communication.

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Appendix: 11b[e] Operation Principles

802.11b[e] ASIC implements the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be interpreted as a Multi Inputs Multi Outputs (MIMO) system or Single Input Multi Outputs (SIMO) system. Its principle of operation is shown as following:

$$Y = AX + N \qquad (1.0)$$

where $\mathbf{X} = [x_1(t), x_2(t), \ldots x_N(t)]^T$ is N signals to be transmitted; $\mathbf{Y} = [y_1(t), y_2(t), \ldots y_M(t)]^T$ is M received signals from RF; $\mathbf{A}$ is the M by N propagation medium mixing matrix; $\mathbf{N} = [n_1(t), n_2(t), \ldots n_M(t)]^T$ is M additive white noises from M receivers. In the time domain, Eq. 1.0 can be considered when there are either short or non-existent multi-path delays. Our existing analog signal separation demonstration is the implementation under such a situation. When short multi-path delay conditions cannot be met, **AX** in (1.0) can be considered either as a convolution operation or as a frequency domain. Since convolution operations are usually complicated, we will concentrate our effort in the frequency domain cases.

The least squares solution to (1.0) is:

$$\hat{X} = (A^*A)^{-1} A^*Y \qquad (1.1)$$

Where the channel mixing matrix **A** can be either blindly estimated, as what was done in the analog implementation using HJ networks with Bartley matrix, or characterized by using the training signal which is the preamble of the Physical Layer Convergence Protocol (PLCP) in 820.11b.

The performance enhancement of the multi-antenna (SIMO) Access Point (AP) is beneficial from two aspects:

1). The transmitted and received power is M times larger than the traditional single transmitter-single receiver (SISO) AP. For noise from multipath delays, the enhancement provides a very good way of equalization. The signals after equalization will be at least M times strong than the single receiver system. If $M = 4$, the increase in the received power will be translated to a 2x increase in range, as shown in Eq. 1.2.

$$P = M^*p_0^*(2^*r)^{-2} = p_0^*r^{-2} \qquad (1.2)$$

Where P is the power received by $M = 4$ receivers, p_0 is the power received at a unit distance from the radiator.

2). When the multipath delays are long enough, the multipath effect can produce a frequency selective fading. The frequency selective fading effect means that the received

signal $S(t)$ at frequency f_1 — $s_1(t)$ is much weaker than the received signal $S(t)$ at frequency f_2 — $s_2(t)$. The effect can be illustrated as following:

$$s_1(t) = e^{-i2\pi f1t} + e^{-i2\pi f1(t+\Delta t)} = e^{-i2\pi f1t}(1 + e^{-i2\pi f1\Delta t}) \quad (1.3a)$$
$$s_2(t) = e^{-i2\pi f2t} + e^{-i2\pi f2(t+\Delta t)} = e^{-i2\pi f2t}(1 + e^{-i2\pi f2\Delta t}) \quad (1.3b)$$

where $S(t)$ is the resulted signal from the combination of the two paths, $s_1(t)$ and $s_2(t)$, which are the frequency components of the signal $S(t)$ at frequency f_1, frequency f_2, respectively. In $(1.3a)$ and $(1.3b)$, the two paths are assumed to have the same amplitude but with a delay difference Δt. To see the frequency selective fading effect, one can let $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$, which translates $(1.3a)$ and $(1.3b)$ to:

$$(1 + e^{-i2\pi f1\Delta t}) = 0 \quad (1.3c)$$
$$(1 + e^{-i2\pi f2\Delta t}) = 2 \quad (1.3c)$$

For the smallest possible Δt to produce the effect, $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$.

$$f_1\Delta t = 1/2 \quad (1.3e)$$
$$f_2\Delta t = 1 \quad (1.3f)$$

Therefore

$$(f_2 - f_1) = 1/(2\Delta t) \quad (1.3g).$$

For 802.11b systems, the bandwidth is 22MHz. If f_2 and f_1 are two frequency points in that band, one can see for $f_2 - f_1 = 11\text{MHz}$, $\Delta t = 46\text{ns}$. This means that delay is as small as 46ns, whereby certain conditions can produce a severe frequency selective fading. The delay difference of 46ns can be translated to a path difference of 14 meters, which can be easily seen in SOHO environments. When the wireless device bandwidth continues to increase for the non-802.11 applications, the path difference would further decrease and making it easier to see.

When the frequency selective fading happens, the performance of the multi-antenna AP is much better than that of the traditional single transmitter-single receiver AP. The traditional AP handles frequency selective fading with an equalizer. However, as shown in $(1.3c)$, the signal component $s_1(t)$ at frequency f_1 is zero and, therefore, there would be a lack of a signal to equalize with. The traditional AP has only two options: either switch to a lower data rate mode, and thereby use the processing gains to compensate the frequency null, or switch to the other antenna. The trade off of the 1st option is a slower data rate. The later option does not guarantee the absence of the frequency selective fading at the different frequency f_1 for the other antenna. At the same time the traditional AP does not take the advantage of the fact that we have better reception at frequency f_2.

The multi-antenna AP can use (1.1) to automatically compensate any frequency null in the information from the other antenna, and provides an optimum solution for the reception when the frequency selective fading happens.

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WLAN Access Point Enhancement ASIC Design Description Document

Shaolin Li

Revision Number: 0.1

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1. Revision History

Revision	Description	Author
0.1	Initial Draft	Shaolin Li
0.2		
0.3		

2. Introduction

This document describes the algorisms to support the WLAN 802.11b enhancement ASIC 11b[e] and its functional blocks. 11b[e] intends to be used in the WLAN 802.11b access point with multiple antenna, RF receivers and transmitters. 11b[e] serves as a scalable signal processing engine for all functions of range and speed enhancement in the WLAN 802.11b physical layer. The hardware and software changes for the enhancement are only limited in the access point. The mobile unit will be a standard 802.11b device.

The focus in the following sections will be on the general principles of the system, the system aspects of the design describing the functionality that needs to be provided by the chip and then defining the internal blocks within the chip that implement a particular functionality. Therefore, this document should serve as a reference for the architecture of the chip within a complete system.

A complementary document to the present one will include the signal level description of the blocks within 11b[e]. The detailed documentation of all internal signals of the chip will be compiled as part of the implementation process.

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3. 11b* Operation Principles

802.11b* ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be understood as a Multi Inputs Multi Output (MIMO) system or Single Input Multi Output (SIMO) system. Its principle of operation will show as following:

$$Y = AX + N \qquad (1.0)$$

where $\mathbf{X} = [x_1(t), x_2(t), \ldots x_N(t)]^T$ is $\mathbf{N}$ signals to be transmitted; $\mathbf{Y} = [y_1(t), y_2(t), \ldots y_M(t)]^T$ is $\mathbf{M}$ received signals from RF; $\mathbf{A}$ is the $\mathbf{M}$ by $\mathbf{N}$ propagation medium mixing matrix; $\mathbf{N} = [n_1(t), n_2(t), \ldots n_M(t)]^T$ is $\mathbf{M}$ additive white noises from $\mathbf{M}$ receivers. In the time domain, Eq. 1.0 can be considered as either multi-path delays are short or does not exist. Our existing analog signal separation demonstration is the implementation under such situation. When those conditions that multi-path delays are small cannot be met, $\mathbf{AX}$ in Eq. 1.0 either can be considered as convolution operation or it is in the frequency domain. Usually the convolution operations are complicated, we will concentrate our effort in the frequency domain cases.

The least squares solution to Eq. 1.0 is:

$$X = (A^*A)^{-1} A^*Y \qquad (1.1)$$

Where the channel mixing matrix $\mathbf{A}$ can be either blindly estimated as what was done in the analog implementation using HJ networks with Bartley matrix, or using the training signal which is the preamble of the Physical Layer Convergence Protocol (PLCP) in 820.11b.

The performance enhancement of the multi-antenna (SIMO) Access Point (AP) is benefited from two aspects:

1). The transmitted and received power is M times larger than the traditional single transmitter-single receiver (SISO) AP. When the noise mainly coming from the multipath delays, the enhancement provides a very good way of equalization for the multipath. The signals after equalization will be at least M times strong than the single receiver system. If $M = 4$, the increase in the received power will be translated to 2x range increase, since

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$$P = M^*p_0^*(2^*r)^{-2} = p_0^*r^{-2} \quad (1.2)$$

Where P is the power received by $M = 4$ receivers, p_0 is the power received at an unit distance from the radiator.

2). When the multipath delays are long enough, the multipath effect can produce a frequency selective fading. The frequency selective fading effect means that the received signal $S(t)$ at frequency f_1 -- $s_1(t)$ is much weaker than the received signal $S(t)$ at frequency f_2 -- $s_2(t)$. The effect can be illustrated as following:

$$s_1(t) = e^{-i2\pi f1t} + e^{-i2\pi f1(t+\Delta t)} = e^{-i2\pi f1t}\,(1 + e^{-i2\pi f1\Delta t}) \quad (1.3a)$$

$$s_2(t) = e^{-i2\pi f2t} + e^{-i2\pi f2(t+\Delta t)} = e^{-i2\pi f2t}\,(1 + e^{-i2\pi f2\Delta t}) \quad (1.3b)$$

where $S(t)$ is the resulted signal from the combination of the two paths, $s_1(t)$ and $s_2(t)$ are the frequency components of the signal $S(t)$ at frequency f_1, frequency f_2, respectively. In (1.3a) and (1.3b), the two paths are assumed to have the same amplitude but with a delay difference Δt. To see the frequency selective fading effect, one can let $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$, which translates (1.3a) and (1.3b) to:

$$(1 + e^{-i2\pi f1\Delta t}) = 0 \quad (1.3c)$$

$$(1 + e^{-i2\pi f2\Delta t}) = 2 \quad (1.3c)$$

For the smallest possible Δt to produce the effect of $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$

$$f_1\Delta t = 1/2 \quad (1.3e)$$

$$f_2\Delta t = 1 \quad (1.3f)$$

Therefore

$$(f_2 - f_1) = 1/(2\Delta t) \quad (1.3g)$$

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In the 802.11b system, the bandwidth is 22MHz. If f_2 and f_1 are two frequency points in the band, one can see for $f_2 - f_1 = 11MHz$, $\Delta t = 46ns$. That means the delay as small as 46ns, at some favorite conditions can produce a severe frequency selective fading. The delay difference of 46ns can be translated a path difference 14 meters, which can be easily seen in SOHO environments. When the wireless device bandwidth increases for the none 802.11 applications, the path difference will decrease and to be seen even easer.

When the frequency selective fading happens, the performance of the multi-antenna AP is much better than that of the traditional single transmitter-single receiver AP. The traditional AP deals the frequency selective fading with an equalizer. However, as shown in (1.3c), the signal component $S_1(t)$ at frequency f_1 is zero and therefore there is no signal to equalize with. The traditional AP only has two options: either switch to the low data rate mode and using the processing gain to compensate the frequency null, or switch to the other antenna. The trade off of the former option is a slow data rate. The later option does not have the guaranty of absence of the frequency selective fading at the different frequency f_l for the other antenna. At the same time the traditional AP does not take the advantage of the fact that we have a very good reception at frequency f_2.

In contra to the traditional AP, the multi-antenna AP uses (1.1) to compensate any frequency null from the information from the other antenna automatically, and provides an optimum solution for the reception when the frequency selective fading happens.

Fig 1 shows the signal processing structure to realize the algorithm above. Fig 2 shows a possible ASIC implementation of the signal processing structure. This chip can realize an added-on scalable architecture through multi-transceiver.

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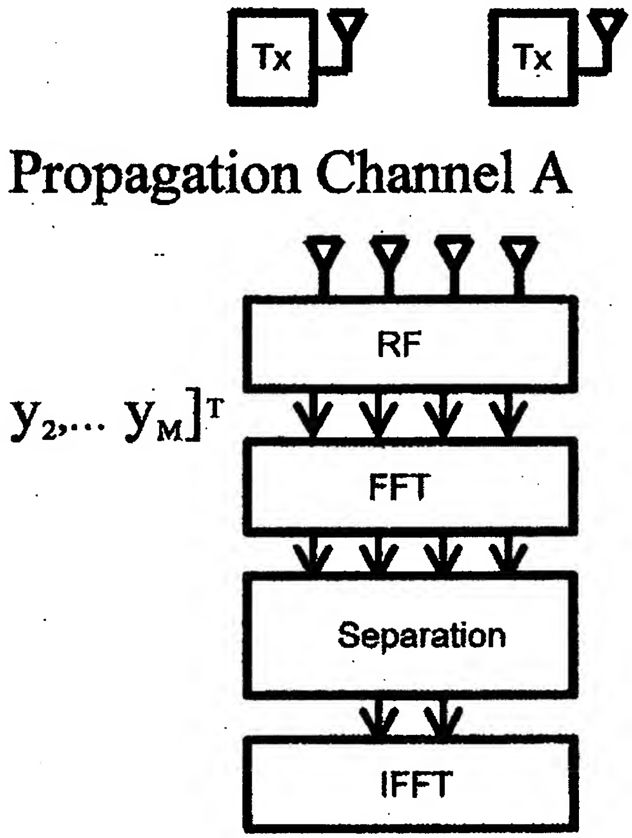

$$\mathbf{Y} = [y_1, y_2, \ldots\ y_M]^T$$

$$\mathbf{X} = [x_1, x_2, \ldots\ x_N]^T$$

Fig. 1
Principle of Spatial Separation

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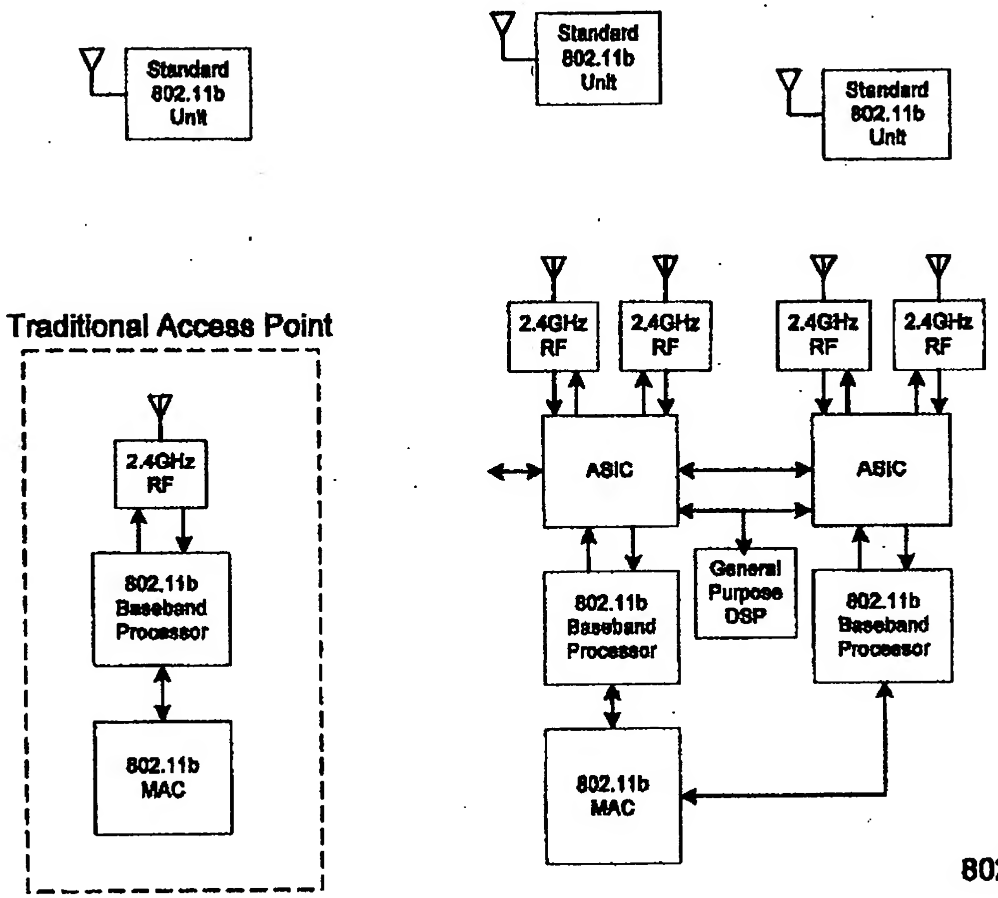

Fig. 2
Configuration for
802.11b enhancement

The 802.11b WLAN Access Point enhancement ASIC can dramatically increase the performance of the 802.11b system. The though-put of 802.11b system under various propagation conditions is shown in Fig. 1. The green area in Fig.1 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 1.

4. 11b[e] Functionality

802.11b[e] ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It includes the following functions:

General

- Provide a micro-controller interface for software access to internal registers of 11b[e] as well as reading/writing of signaling messages
- Generate a set of clocks for all internal modules from a 44MHz master clock

Receive Mode

- Performance A/D conversion for the received I and Q baseband signals.
- Acquiring the timing of the received signal samples relative to the local PN code in PLCP preamble, synchronizing the signal samples to FFT frame.
- Transforming the received signal samples of multiple RF to the frequency domain using FFT.
- Using the known FFT of preamble to estimate the RF channels.
- Separate the signals according to Eq. 1.1
- Reconstruct the received signal in the time domain.
- Convert recovered signal to the analogy form and send out to a standard 802.11b DSSS receiver for decoding.

Transmit Mode

- Framing of the information bit stream to be transmitted
- Symbol mapping/encoding of the bits in a transmit frame
- Scrambler the transmitted data to be transmitted
- Modulating these symbols with Baker or CCK codes necessary for spreading the spectrum of the transmitted data
- Pre-equalize the generated waveforms in frequency domain.
- Make D/A conversion

5. Brief Specification of 802.11b DSSS

This section briefly overviews Direct Sequence Spread Spectrum (DSSS) physical layer.

5.1 802.11b Physical Layer Specification

The following paragraph specifies the High Rate extension of the PHY for the Direct Sequence Spread Spectrum (DSSS) system known as the High Rate PHY for the 2.4GHz band designated for ISM applications. 802.11b DSSS system builds on the data rate capabilities, as described in IEEE Std 802.11, 1999 Edition, to provide 5.5 Mbit/s and 11 Mbit/s payload data rates in addition to the 1 Mbps and 2 Mbps rates. To provide the higher rates, 8-chip complementary code keying (CCK) is employed as the modulation scheme. The chipping rate is 11 MHz, which is the same as the DSSS system described in IEEE Std 802.11, 1999 Edition, thus providing the same occupied channel bandwidth. The basic new capability of High Rate Direct Sequence Spread Spectrum (HR/DSSS) uses the same PLCP preamble and header as the DSSS PHY, so both PHYs can co-exist in the same BSS and can use the rate switching mechanism as provided. In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the radio frequency LAN system to be improved as technology allows the implementation of these options to become cost effective. An optional mode replacing the CCK modulation with packet binary convolutional coding (HR/DSSS/PBCC) is provided. The key parameters of this interface, most relevant to, are listed in the Table 1.

Table 1. Summary of 802.11b Specification

Parameter	Specification
Access Protocol	CSMA/CA (Carrier-sense Multiple Access with Collision Avoidance)
Duplexing method	Time Division Duplex (TDD)
Modulation	BPSK / QPSK/CCK/PBCC
Error Correction	Rate ½ K=7 Convolutional Code

Parameter	Specification
	for PBCC
Spreading	Baker
Chip Rate	11 Mcps
Frame length	Various
Processing Gains	11 at 1,2 Mbps
Bearer Rates	1, 2, 5.5 11 Mbps
High Rate Mode	CCK;PBCC

5.1.1 Frame Structure

The following figure shows the frame structure of 802.11b DSSS physical layer. Figure 4 shows the format for the interoperable (long) PPDU, including the High Rate PLCP preamble, the High Rate PLCP header, and the PSDU. The PLCP preamble contains the following fields: synchronization (Sync) and start frame delimiter (SFD). The PLCP header contains the following fields: signaling (SIGNAL), service (SERVICE), length (LENGTH), and CCITT CRC-16. Each of these fields is described in detail in 18.2.3. The format for the PPDU, including the long High Rate PLCP preamble, the long High Rate PLCP header, and the PSDU, do not differ from IEEE Std 802.11, 1999 Edition for 1Mbit/s and 2 Mbit/s.
The only exceptions are
a) The encoding of the rate in the SIGNAL field;
b) The use of a bit in the SERVICE field to resolve an ambiguity in PSDU length in octets, when the length is expressed in whole microseconds;
c) The use of a bit in the SERVICE field to indicate if the optional PBCC mode is being used;
d) The use of a bit in the SERVICE field to indicate that the transit frequency and bit clocks are locked.

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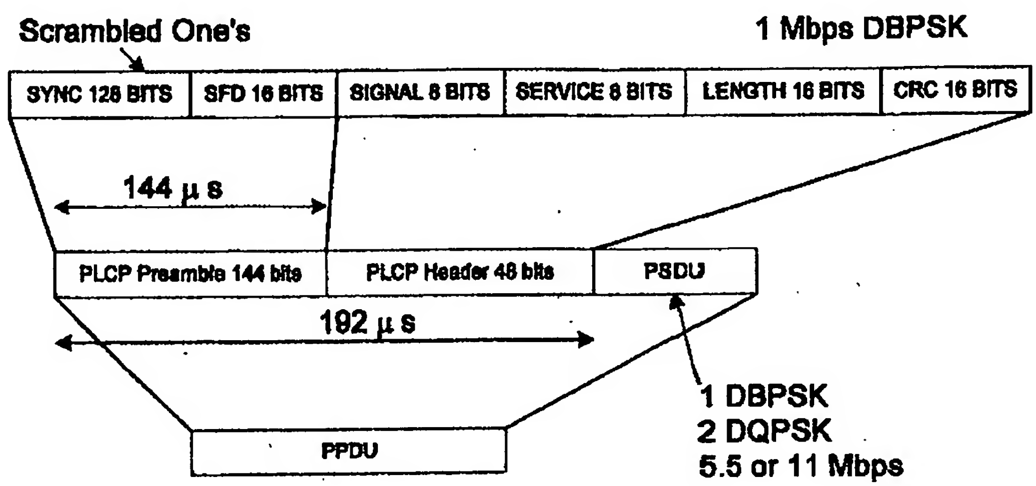

Fig. 4 Long PLCP PPDU format

6. 11b[e] ASIC Blocks, Interfaces and Their Functionality

The internal block diagram of 11b[e] ASIC is shown in Figure 5. 11b[e] ASIC consists of the following major functional blocks and interfaces:

- Clock Generator
- SDRAM Buffer Interface Address Generator
- Three 512-point FFT/IFFT switch able blocks
- Separation Matrix Multiplier
- On Chip Parameter Memory Bank
- Inter-chip Data Exchange Interface
- DSP Interface
- Preamble Acquisition Module
- Four 6bit A/D at 22MHz
- Four 8bit D/A at 44MHz

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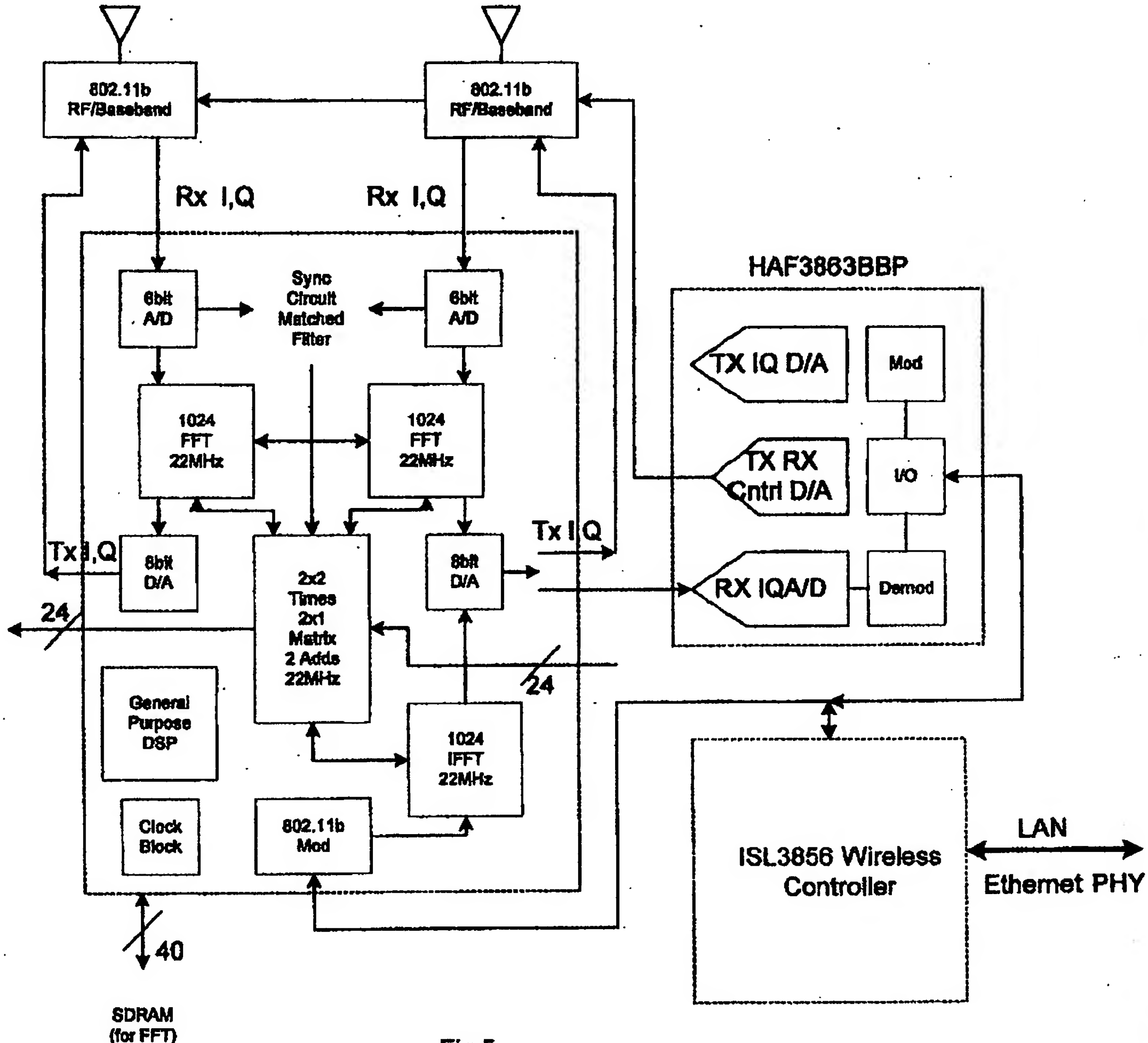


Fig.5
High Level Block Diagram of
11b[e] ASIC

6.1 Clock Generator

This module provides all necessary clocks and control signals for other modules of 11b[a]. The key features of this module are described below.

6.1.1 FFT and IFFT Module Clock

The clock generator provides FFT/IFFT modules for the system clock of FFT operation. The system clock cycles for each FFT frame are calculated as the following:

number of passes = ceiling[($\log_2$points)/2]

= 5

number of clock cycles per pass = 14 + points + ceiling[$\log_2$(twiddlewidth)]

= 14 + 512 + 4 = 530

number of clock cycles per frame = number of passes * number of clock cycles per pass

= 2650

The minimum clock speed for the FFT/IFFT module with 16% safety margin is:

Clock Rate = 2650/512*22MHz*116% = 132MHz

The clock rate 132MHz is 3 multiple of the basic clock rate 44MHz. The clock rate 132MHz is generated by using PLL to locked on the system clock 44MHz. The interactions and coordination between the FFT Input SDRAM Buffer and FFT modules is done through a third sub-module, the Arbiter.

6.1.2 FFT Start Frame Timing Control

The FFT start frame timing control signal is provided by the Preamble Acquisition Module. This signal indicates the start data position pointer in FFT Input SDRAM Buffer.

6.1.3 Separation Multiplier Start Timing Control

The clock generator module also provides Separation Multiplier Start Timing Control.

6.2 SDRAM Buffer Interface Address Generator

The interface either uses a general purpose DSP or a configurable interface logic. It still is an open question.

6.3 512-point FFT/IFFT switch able blocks

There are three 512-point FFT blocks operating at 132MHz system clock. The blocks can be switched between FFT and IFFT. The input real and imaginary data are 8 bit.

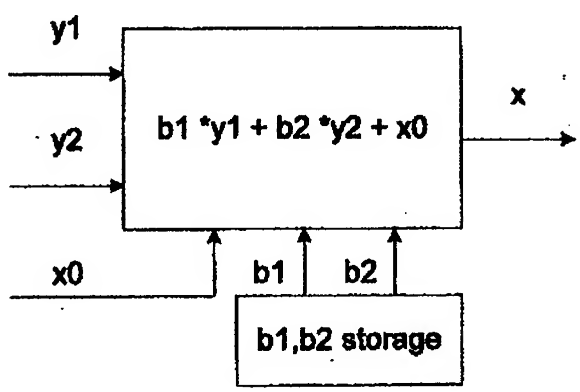


Fig 4 Separation Matrix Multiplier

6.4 Separation Matrix Multiplier

This module essentially perform the following operation at 22MHz when is in receiving mode

$$x = b_1 * y_1 + b_2 * y_2 + x_0$$

where b_1 and b_2 are calculated equalization coefficients; x_0 is the adjacent ASIC recovered signal; y_1 and y_2 are two received data from the current ASIC two baseband channels; x is the recovered signal. All of them are complex numbers. The operations are 2 complex multiplications and 2 complex additions. The resolution of b_1, b_2, x_0, y_1, y_2, x are 12 bits.

This module perform the following operation at 22MHz when is in transmitting mode

$T_1 = b_1 * x_t,$ $T_2 = b_2 * x_t,$

where b_1 and b_2 are calculated pre-equalization coefficients; x_t is the to-be transmitted signal; T_1 and T_2 are two baseband signals to responding antenna;

6.5 On Chip Parameter Memory Bank

The coefficients b_1, b_2 are the estimated channel equalization parameters for a particular 802.11b station. The on-chip parameter memory bank holds 2*512 complex parameters for each 802.11b station. If there are 10 such stations to handle, the size of memory bank is 2*2*512*12*10 = 491520 bits. The on-chip parameter memory bank is supposed to be SRAM.

6.6 Inter-chip Data Exchange Interface

The interface is designed to transfer the data y_0 from the adjacent ASIC and to transfer y_0 the next ASIC.

6.7 DSP Interface

The DSP interface will depends on the general purpose DSP we have chosen.

6.8 Preamble Acquisition Module

The acquisition block performs the initial preamble PN code timing acquisition in the receiver. The processing in this block is based on performing a set of matched filtering operations. This approach is adopted primarily to provide a fast acquisition mechanism.

The matched filtering operation is performed by four 16 chip matched filters, providing a filter that is matched to any 64 chip complex sequence. The input to the matched filter is the stream of received samples at twice the chip rate. Thus, the timing accuracy provided by the Acquisition block is of the order of ¼ of a chip duration.

The block diagram of the matched filter structure is shown in Figure 6.

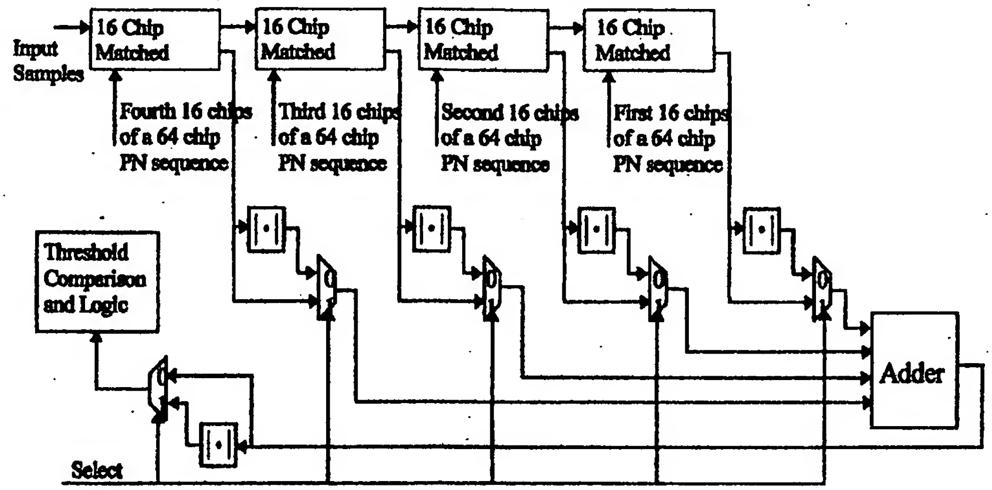


Figure 6. Block Diagram of the Preamble Acquisition Module.

6.9 Four 6bit A/D at 22MHz

There are four 6bit 22MHz A/D in the ASIC. Each baseband signal will need 2 A/Ds (I and Q) to convert it to digital signals.

6.10 Four 8bit D/A at 44MHz

There are four 8bit 44MHz D/A in the ASIC. Each RF path needs 2 D/As (I and Q) to transmit signal to the modulater.

6.10.1 DC Offset Estimation

To estimate the DC value of the signal plus interference we simply low pass filter the received I/Q samples over the entire received frame. The resulting filter output is then subtracted from the I/Q samples. The low-pass filter is a single pole IIR filter of the type:

$$y_k = (1-\alpha)y_{k-1}+\alpha\, x_k$$

where k is the sample index.

6.10.1.1 DC Offset Correction

The estimated offset values in the I and Q paths may be fed back to the ADC outputs to cancel out the offsets from the analog portion of the system. This will be accomplished via a pair of adders immediately following the ADCs, as shown in Figure 7.

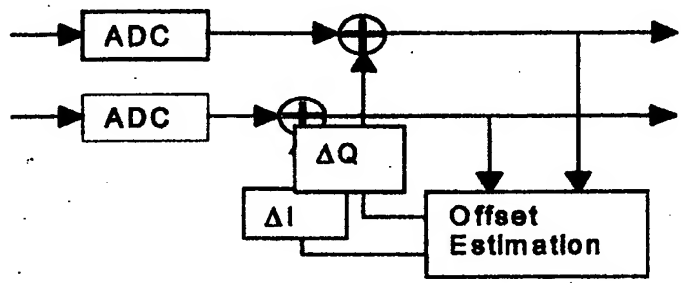


Figure 7. DC Offset Correction.

The offset values will be represented by 5 bit words. This will allow us to correct offsets of less than 7% of the full amplitude swing in the received signal.

7. Operating Procedures

This section describes some of the system operation procedures that rely on explicit support from 11b. More specifically, the portion of system operations that deals with the physical layer aspect of preamble acquisition and connection enhancement are described as below.

7.1 Operation Philosophy

The intention of 802.11b WLAN Access Point enhancement is to realize an added-on scalable architecture through multi-transceiver to dramatically increase the performance of the 802.11b system. The projected though-put of 802.11b system under various propagation conditions is shown in Fig. 8. The green area in Fig.8 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 8. The enhanced receiver portion and the standard receiver will operate simultaneously. When a STA is the green, the communication between AP and STA through the standard 802.11b chip set as long as the AP satisfies with the link through-put. Whenever the STA in the red area or in low data rate green area due to the poor reception or the distance from AP, the enhancement portion can kick in, estimate the channel using the frame of data which the standard 802.11b chip set can not decode on, transfer the data mainly under the mode **point coordination function (PCF).**

The PCF provides contention-free frame transfer. The PC shall reside in the AP. It is an option for an AP to be able to become the PC. All STAs inherently obey the medium access rules of the PCF, because these rules are based on the DCF, and they set their NAV at the beginning of each CFP. The operating characteristics of the PCF are such that all STAs are able to operate properly in the presence of a BSS in which a PC is operating, and, if associated with a point-coordinated BSS, are able to receive all frames sent under PCF control. It is also an option for a STA to be able to respond to a contention-free poll (CF-Poll) received from a PC. A STA that is able to respond to CF-Polls is referred to as being CF-Pollable, and may request to be polled by an active PC. CF-Pollable STAs and the PC do not use RTS/CTS in the CFP. When polled by the PC, a CF-Pollable STA may transmit only one MPDU, which can be to any destination (not just to the PC), and may "piggyback" the acknowledgment of a frame received from the PC using particular data frame subtypes for this transmission. If the data frame is not in turn acknowledged, the CF-Pollable STA shall not retransmit the frame unless it is polled again by the PC, or it decides to retransmit during the CP. If the addressed recipient of a CF transmission is not CF-Pollable, that STA acknowledges the transmission using the DCF acknowl-edgment rules, and the PC retains control of the medium. A PC may use contention-free frame transfer solely for delivery of frames to STAs, and never to poll non-CF-Pollable STAs.

7.2 Preamble Acquisition

Preamble acquisition is performed by the ASIC to line up the FFT frame with the incoming data stream. After the preamble acquisition, the FFT frame in the SYNC of the preamble will provide the channel estimation of the following separation and combining.

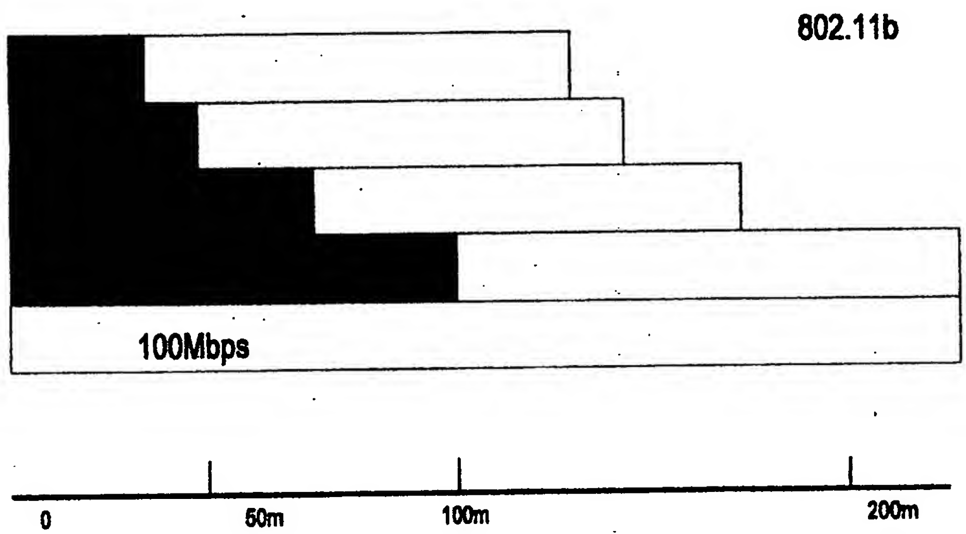


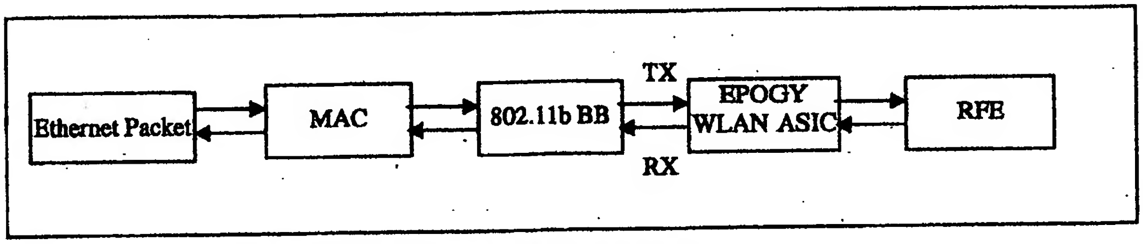
Fig. 8
802.11b enhancement

WLAN Enhancement ASIC

Operation Mode Constraints

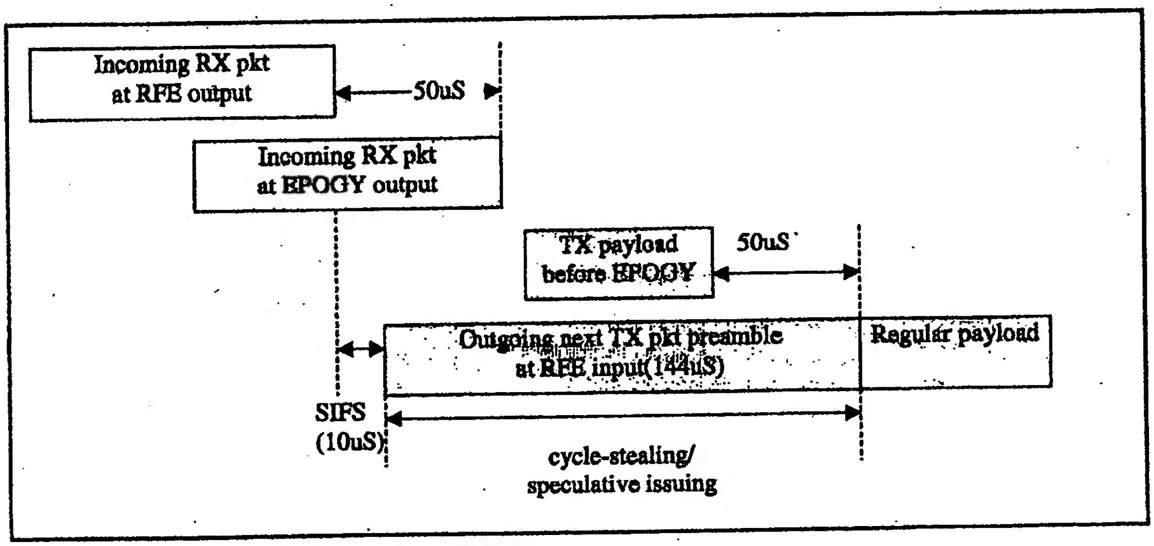
2 Operation Constraints

As shown in Figure 1, an 802.11b transceiver with EPOGY WLAN Enhanced ASIC between the 11b baseband processor and the RFE. Since an average of 50uS is introduced in the RX data path, a special "cycle-stealing" concept has been applied to avoid the violation of IEEE 802.11 SIFS or PIFS timing.



• Figure 1 EPOG WLAN Enhanced 802.11b Transciever

As shown in , SIFS(10uS) after the end of previous RX packet, a pre-stored(?? Can we) 144us preamble is issued before the previous RX packet is fullu decoded. Therefore the 802.11 SIFS timing can be maintained.



• Figure 2 Cycle-stealing timeline

2.1 Assumptions

To implement the speculative issuing, the following protocol assumptions have to be made:

1) For a short 802.11 frame, the "Destination Address field" (DA) within the incoming RX packet may not be decoded in time for the AP decide to start sending.

2) For a short 802.11 frame, the "Frame Type" within the incoming RX packet may not be decoded in time for the AP decide to start sending.

2.2 Operation mode

The current intended operation mode intended for the EPOGY WLAN enhanced AP is under the Point Coordination Function (PCF). Under the PCF, a contention free period (CFP) is established on the medium. The PCF-capable AP starts the contention free period with a beacon frame, then all the STA can only access the medium after they are "polled" by the AP. In this fashion, the access sequences on the mediums can be easily determined beforehand by the AP. For example, AP-STA1-AP-STA2-AP-STA3-AP-AP-STA4. Note that under this condition, there is no two consecutive STA access on the medium, therefore safe "speculative issung" can be assumed by the AP.

2.3 Constraints

The EPOG WLAN Enhanced ASIC can not operate under the basic DCF (distributed coordination function) mode, since under this mode, there is no pre-defined sequences for the "cycle-stealing" issuing to reference. Although the EPOGY ASIC RX path can be active at all times (parellel to an 11b RX path w/o EPOGY WLAN ASIC delay), the EPOGY ASIC TX path should not be active.

3 Special Considerations

Because of the special "TX wave beaming" capability, the WLAN ASIC helps to transmit TX packet to further recipient(s) at a specific locations instead of all recipients out of regular 802.11b TX range. Special considerations are to taken for the following situations:

3.1 Authentication and Association

Before any STA to associate with an AP, the STA has to authenticate and then associate with the APs by sending out "Authetication" or "association" packets. While these packets are sent by out of (11b regular) range STA to AP in the contention period (CP), apparently the WLAN ASIC enhanced AP can only respond to these far out STA in the following contention-free period (CFP).

It's reasonable that the Expire timers (in terms of multiple of TU==1024 uS) conditions can be satisfied by either a.) AP to treat these requests as high priority, therefore to establish a CFP to respond, or b.) the AP can preset the CFP/CP alternating time ratio to a reasonable range.

Similar scenarios exists in other packets, ex: "Probe request">

3.2 Multiple destination transmission

Beacon frame, broadcast, and multicast are typical packets targeted for multiple destinations (STAs).

For multiple targets spreading across different directions, "multiple sending of the same payloads" method may be required, i.e. a typical 802.11b (w/o WLAN IC) multicasting transmission first to all the in range targets, then followed by location specified (w/ WLAN enhaced ASIC) sending to the out of regular 11b range targets.

For multiple targets in a concentrated area, the associated EQ coefficient array might be combined to form a new hybrid sending EQ coefficients, therefore to cover a specific direction/locality with one packet transmission. However, the EQ coefficient array associated with each STA need to be stored, and an efficient algorithm to determine the new hybrid EQ coefficient array is still to be determined …

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IntelliGain™ Technology

- Introduction to Wireless Challenges and Possible Technical Solutions
- System Implementation for Feasibility Study of IntelliGain™ Technology
- Proposed Wireless Multimedia Demo System

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IntelliGain™ Technology

1. Very low cost and low power: The adaptive signal estimation/separation technology can be implemented as a module using standard 0.35 micron CMOS technology occupying an area of less than 1mm x 1mm with micro-watt power dissipation.

2. Mitigation of Long Delay spread: Very long impulse responses caused by long delay spread can be separated.

3. Blind separation: The separation does not require a priori knowledge of signal sources. No training signals are needed for equalization.

4. Protocol independent: The signal separation/recovery system is transparent to the application protocols and is widely applicable to many wireless applications.

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Technical Challenges

- Wireless channels subject to time-varying impairments
  - Multipath – delay spread, temporal and frequency fading
  - Interference – including multiple access interference
  - Noise – microwaves, ham radio, transmitter/receiver, other wireless devices operating in the same spectrum

- Design Constraints:
  - Power
  - Size

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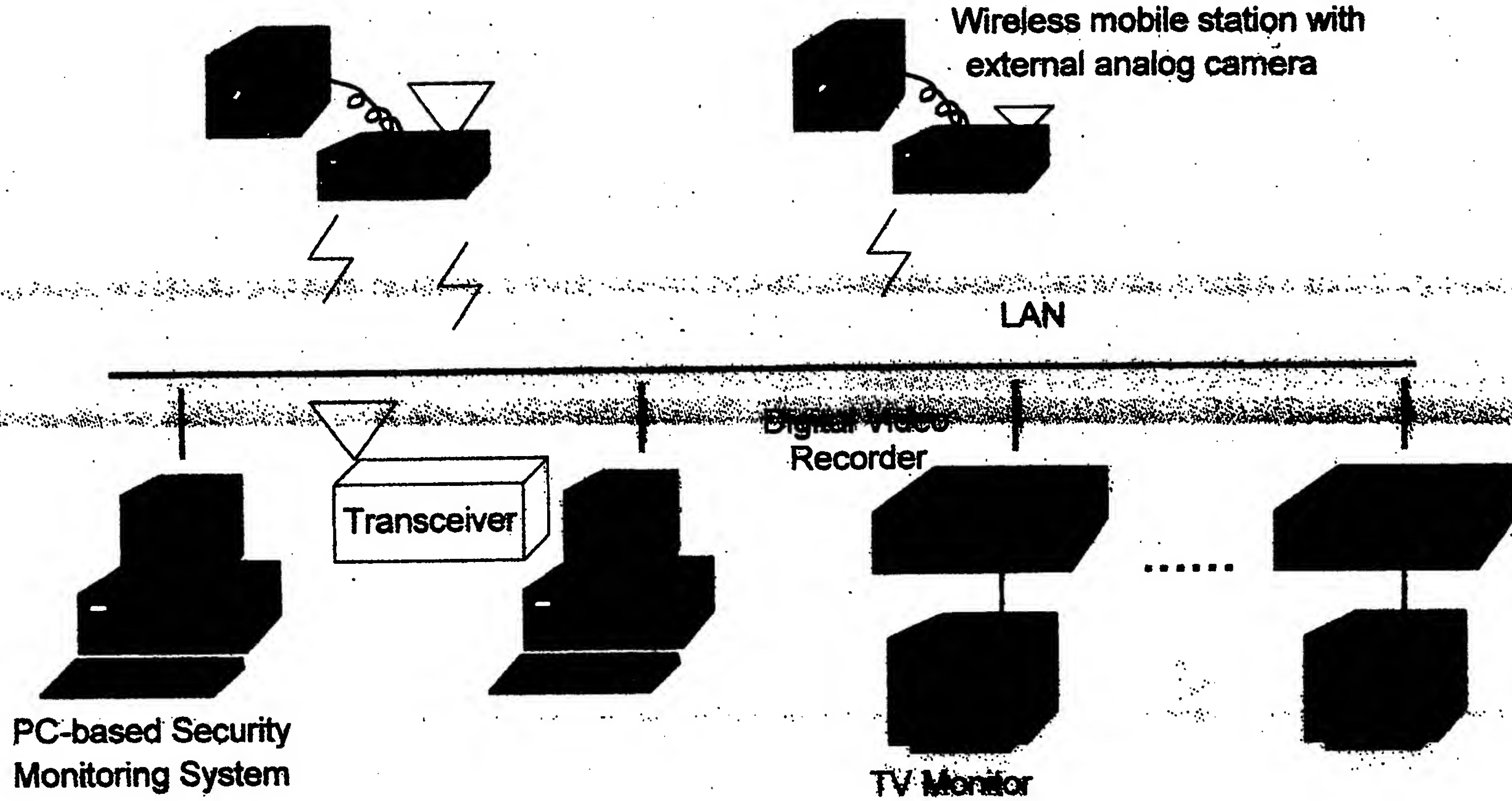
Proposed Wireless Multimedia Demo System



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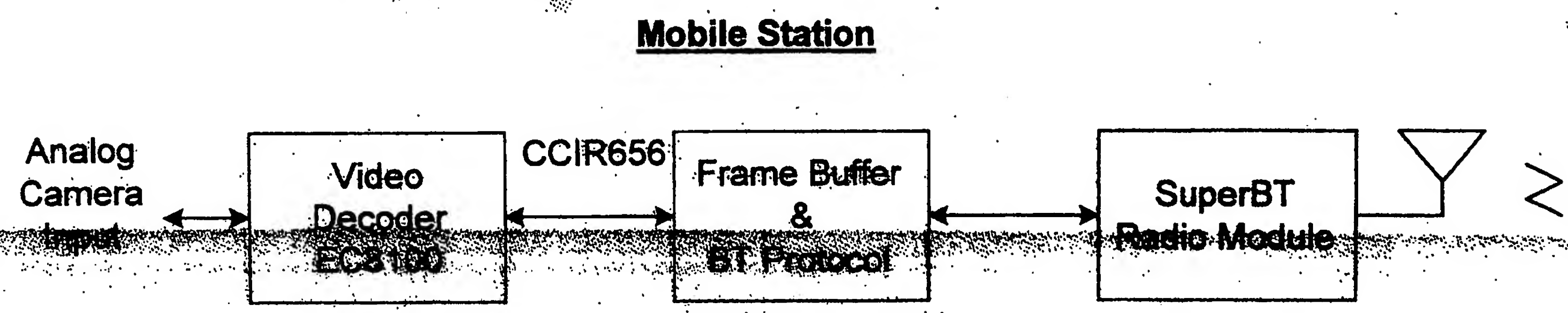
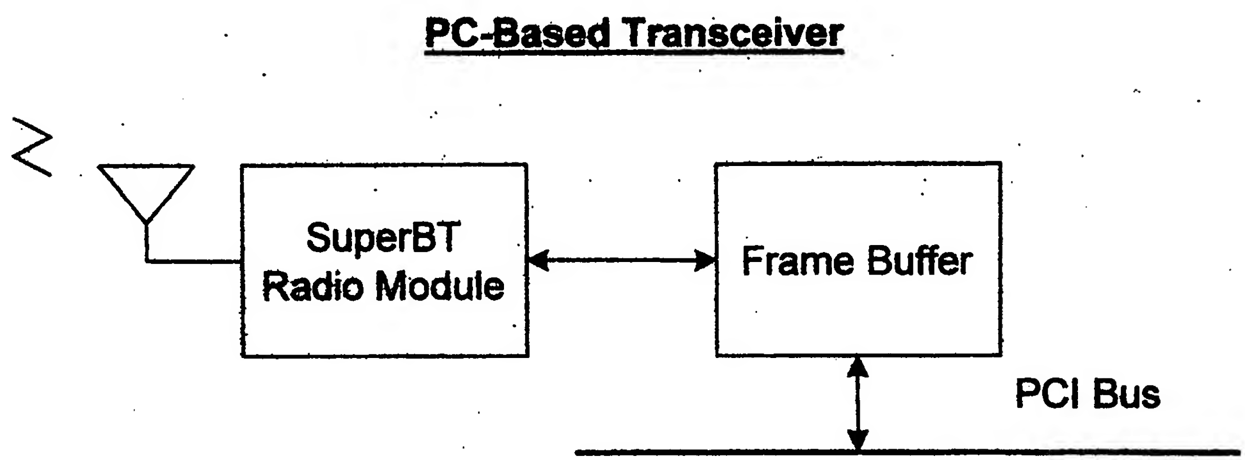
Proposed Wireless Multimedia Demo System





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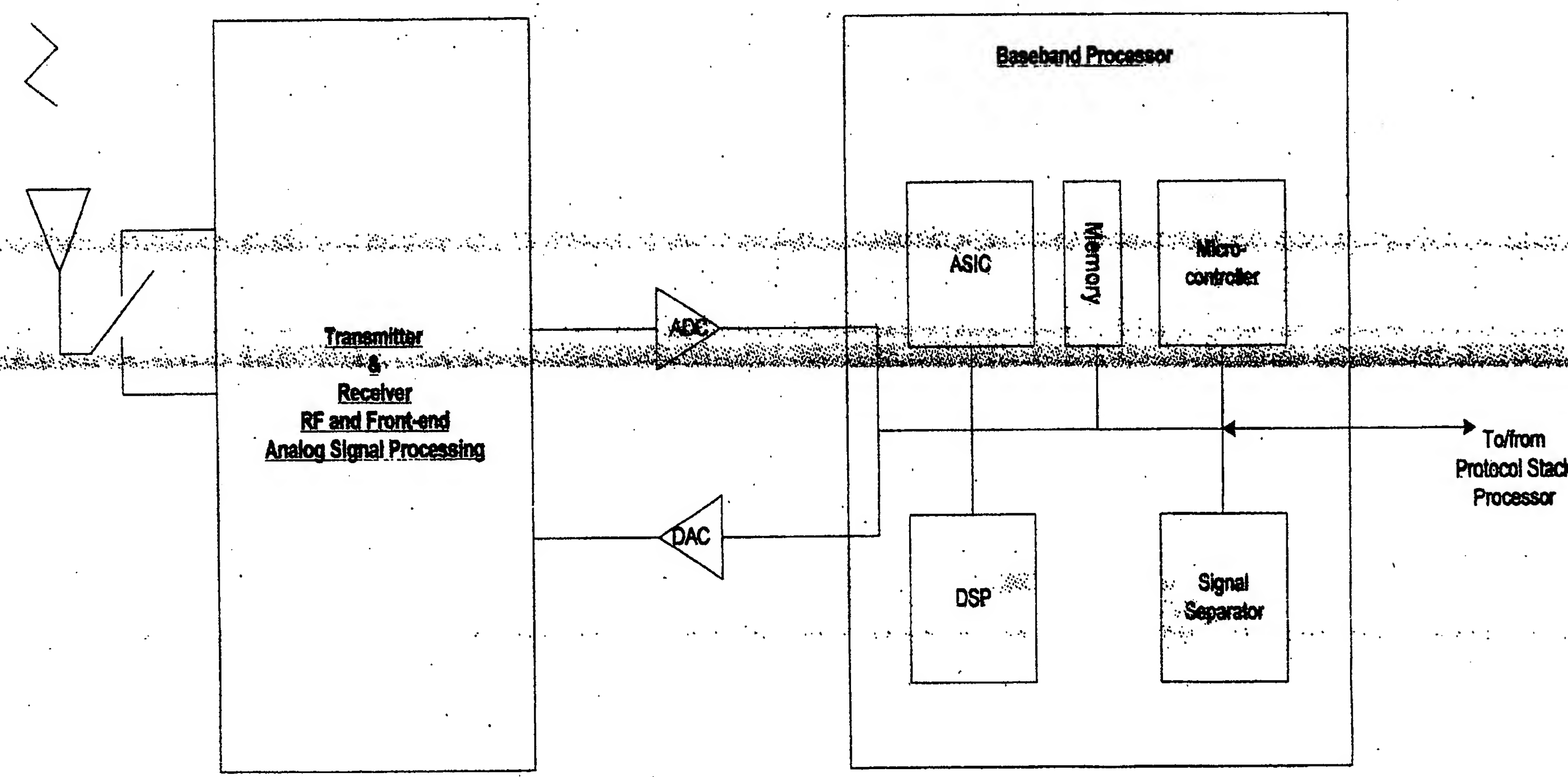
Proposed Wireless Multimedia Demo System



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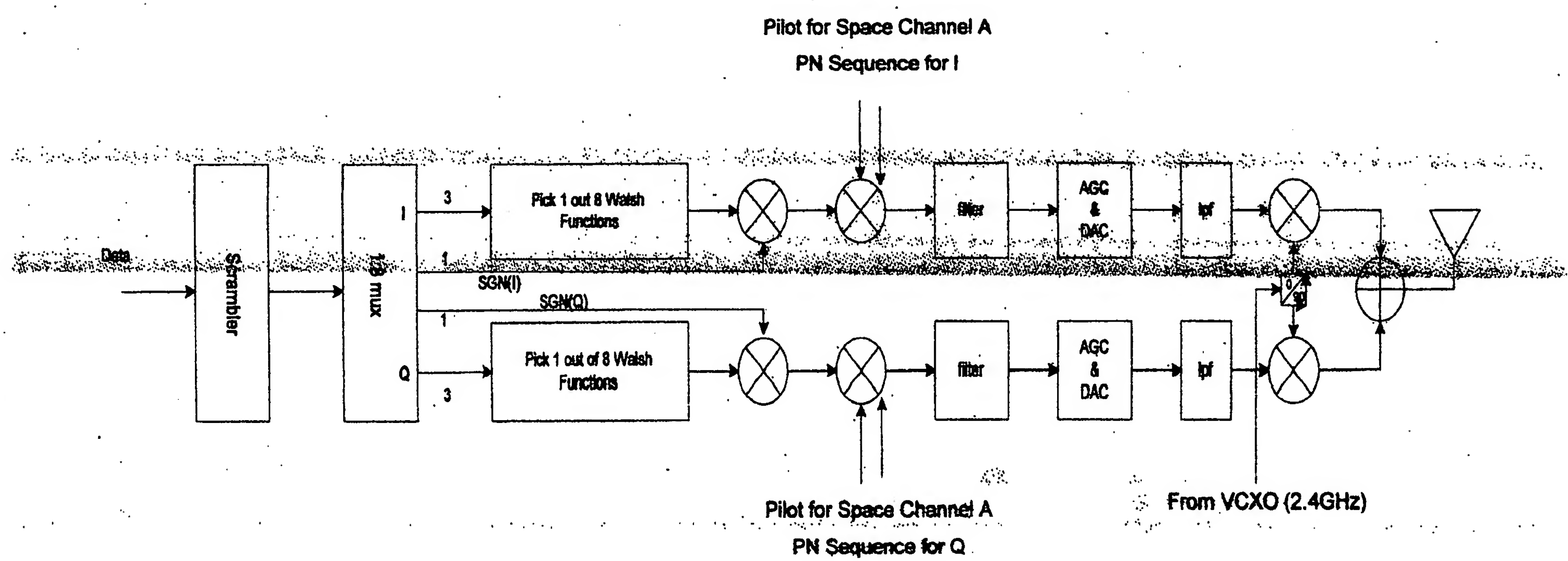
Proposed Wireless Multimedia Demo System

Radio Module Transmitter for Space Channel A



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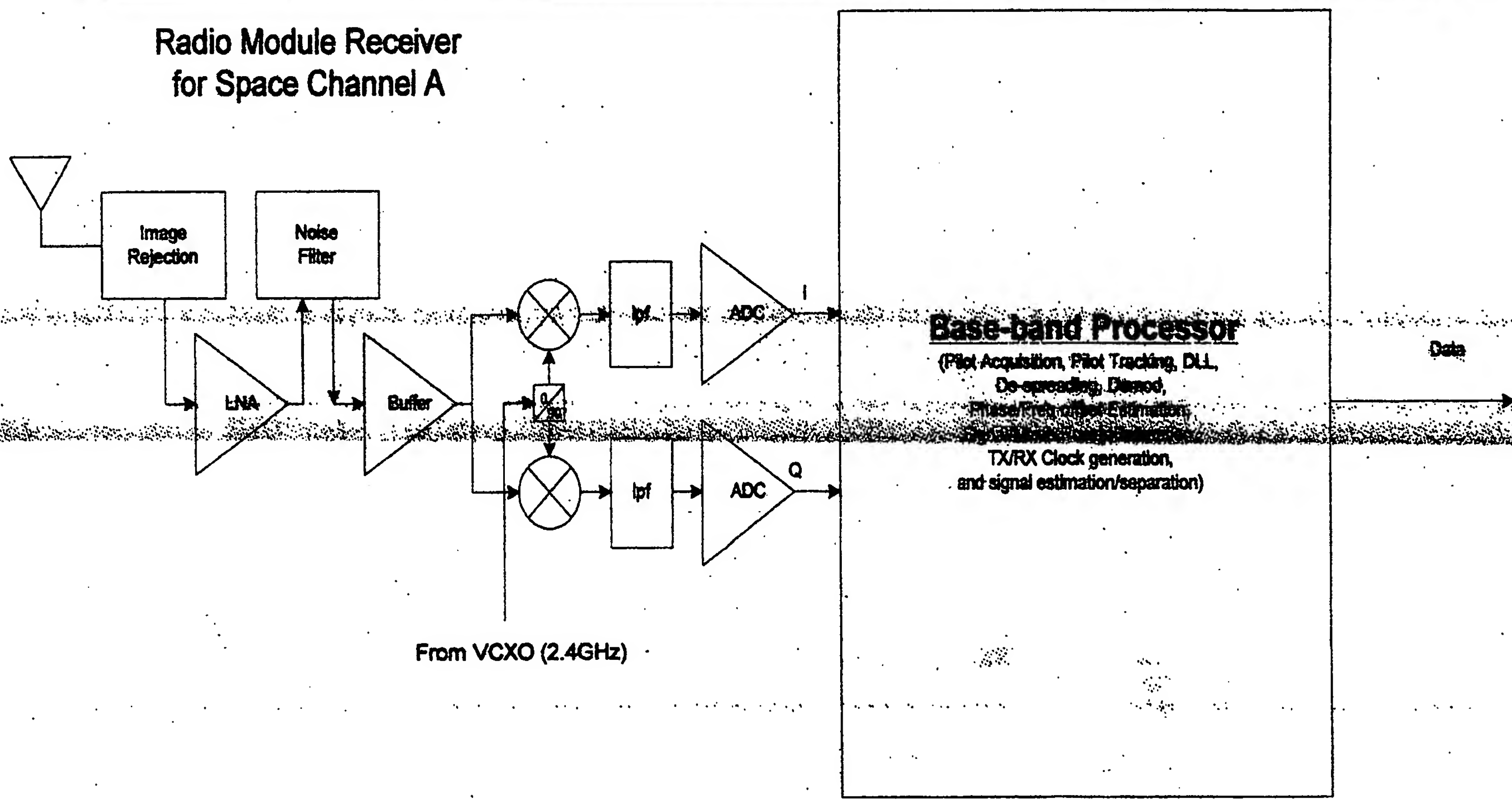
Proposed Wireless Multimedia Demo System

Radio Module Receiver
for Space Channel A



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Proposed Wireless Multimedia Demo System

Carrier Frequency		2.4 GHz (unlicensed)
Bandwidth		4 MHz
Chip Rate		4 Mcps
Symbol (Data) Rate	PG = 8	2 msps (20 mbps)
	PG = 16	1 msps (16 mbps)
	PG = 32	0.5 msps (8 mbps)

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Why CCTV?

- CCTV market is actively seeking wireless & digital video
  - Reduce the installation material and labor costs
  - Allow cameras to be placed virtually anywhere
  - Reduce maintenance costs, allow remote monitoring, and ease of use
  - Needs robust wireless transmission, video/audio compression, compatibility with various standards, security, and low cost
- Epogy has technology/solution that addresses the fundamental issues
- Epogy's initial demonstration of the "core" technology is real-time wireless digital video
- Utilize existing infrastructure

epogy communications

CCTV: Our Solution

- Installation is big issue
  - Layout and placement has to be pre-defined
  - Shortage of skilled labor force
  - Material cost is high
- Wireless signal integrity, quality and cost
  - Digital wireless
  - Independent of standards
  - Low cost and low power
  - Spread spectrum
- Storage of data in terabytes
  - Compression of video 100:1
  - Motion detection

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Possible Applications of Epogy's Technology

- Mobile video communications
  - Office environment (PDAs, Pocket PCs)
  - Home security (child monitoring)
- Video mail (Nintendo Gameboy, PDAs, Pocket PCs)
- Simultaneous viewing between multiple users (Nintendo Gameboy, responding security officer and central office)
- Enable remote wireless video storage (law enforcement, digital cameras)
- Enable remote viewing (day cares, nursing homes)
- Telematics
  - DVD, VCD, VCR in an automobile
  - Movable video on heavy equipment
- Wireless DSL / cable
  - Enable access / viewing to all rooms / units
  - Allows access / viewing by other (enabled) devices

EXHIBIT B

DRAFT

WLAN Access Point Enhancement ASIC Design Description Document

Shaolin Li
December 6, 2004

Revision Number: 0.1

1. Revision History

Revision	Description	Author
0.1	Initial Draft	Shaolin Li
0.2		
0.3		

2. Introduction

This document describes the algorisms to support the WLAN 802.11b enhancement ASIC 11b^e and its functional blocks. 11b^e intends to be used in the WLAN 802.11b access point with multiple antenna, RF receivers and transmitters. 11b^e serves as a scalable signal processing engine for all functions of range and speed enhancement in the WLAN 802.11b physical layer. The hardware and software changes for the enhancement are only limited in the access point. The mobile unit will be a standard 802.11b device.

The focus in the following sections will be on the general principles of the system, the system aspects of the design describing the functionality that needs to be provided by the chip and then defining the internal blocks within the chip that implement a particular functionality. Therefore, this document should serve as a reference for the architecture of the chip within a complete system.

A complementary document to the present one will include the signal level description of the blocks within 11b^e. The detailed documentation of all internal signals of the chip will be compiled as part of the implementation process.

3. 11b^e Operation Principles

802.11b^e ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be understood as a Multi Inputs Multi Output (MIMO) system or Single Input Multi Output (SIMO) system. Its principle of operation will show as following:

$$Y = AX + N \qquad (1.0)$$

where $\mathbf{X} = [x_1(t), x_2(t), \ldots\ x_N(t)]^T$ is N signals to be transmitted; $\mathbf{Y} = [y_1(t), y_2(t), \ldots\ y_M(t)]^T$ is M received signals from RF; $\mathbf{A}$ is the M by N propagation medium mixing matrix; $\mathbf{N} = [n_1(t), n_2(t), \ldots\ n_M(t)]^T$ is M additive white noises from M receivers. In the time domain, Eq. 1.0 can be considered as either multi-path delays are short or does not exist. Our existing analog signal separation demonstration is the implementation under such situation. When those conditions that multi-path delays are small cannot be met, **AX** in Eq. 1.0 either can be considered as convolution operation or it is in the frequency domain. Usually the convolution operations are complicated, we will concentrate our effort in the frequency domain cases.

The least squares solution to Eq. 1.0 is:

$$X = (A^*A)^{-1} A^*Y \qquad (1.1)$$

Where the channel mixing matrix **A** can be either blindly estimated as what was done in the analog implementation using HJ networks with Bartley matrix, or using the training signal which is the preamble of the Physical Layer Convergence Protocol (PLCP) in 820.11b.

The performance enhancement of the multi-antenna (SIMO) Access Point (AP) is benefited from two aspects:

1). The transmitted and received power is M times larger than the traditional single transmitter-single receiver (SISO) AP. When the noise mainly coming from the multipath delays, the enhancement provides a very good way of equalization for the multipath. The signals after equalization will be at least M times strong than the single receiver system. If $M = 4$, the increase in the received power will be translated to 2x range increase, since

$$P = M^*p_0^*(2^*r)^{-2} = p_0^*r^{-2} \qquad (1.2)$$

Where P is the power received by $M = 4$ receivers, p_0 is the power received at an unit distance from the radiator.

2). When the multipath delays are long enough, the multipath effect can produce a frequency selective fading. The frequency selective fading effect means that the received signal $S(t)$ at frequency f_1 --- $s_1(t)$ is much weaker than the received signal $S(t)$ at frequency f_2 --- $s_2(t)$. The effect can be illustrated as following:

$$s_1(t) = e^{-i2\pi f1t} + e^{-i2\pi f1(t+\Delta t)} = e^{-i2\pi f1t}\,(1 + e^{-i2\pi f1\Delta t}) \quad (1.3a)$$

$$s_2(t) = e^{-i2\pi f2t} + e^{-i2\pi f2(t+\Delta t)} = e^{-i2\pi f2t}\,(1 + e^{-i2\pi f2\Delta t}) \quad (1.3b)$$

where $S(t)$ is the resulted signal from the combination of the two paths, $s_1(t)$ and $s_2(t)$ are the frequency components of the signal $S(t)$ at frequency f_1, frequency f_2, respectively. In (1.3a) and (1.3b), the two paths are assumed to have the same amplitude but with a delay difference Δt. To see the frequency selective fading effect, one can let $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$, which translates (1.3a) and (1.3b) to:

$$(1 + e^{-i2\pi f1\Delta t}) = 0 \quad (1.3c)$$

$$(1 + e^{-i2\pi f2\Delta t}) = 2 \quad (1.3c)$$

For the smallest possible Δt to produce the effect of $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$

$$f_1\Delta t = 1/2 \quad (1.3e)$$

$$f_2\Delta t = 1 \quad (1.3f)$$

Therefore

$$(f_2 - f_1) = 1/(2\Delta t) \quad (1.3g)$$

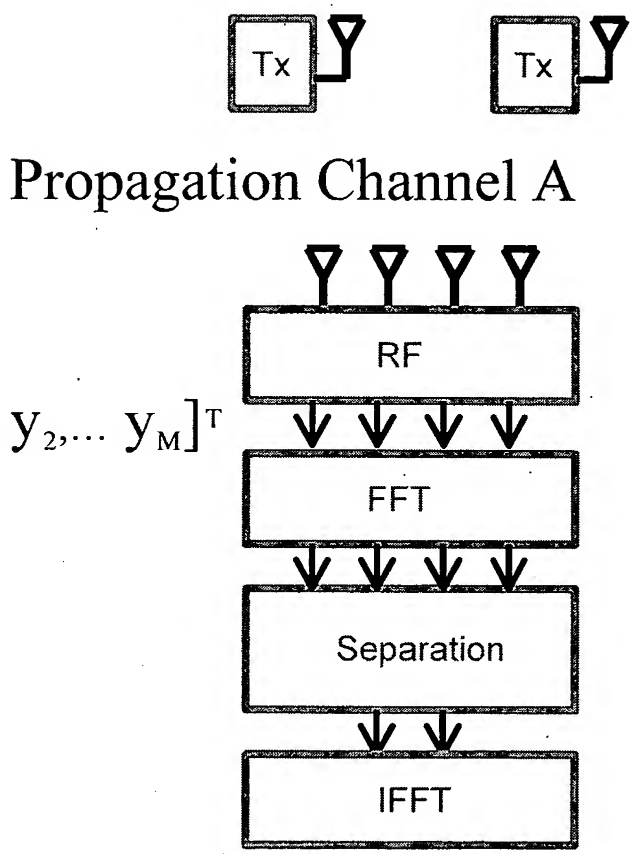
In the 802.11b system, the bandwidth is 22MHz. If f_2 and f_1 are two frequency points in the band, one can see for $f_2 - f_1 = 11\text{MHz}$, $\Delta t = 46\text{ns}$. That means the delay as small as

46ns, at some favorite conditions can produce a severe frequency selective fading. The delay difference of 46ns can be translated a path difference 14 meters, which can be easily seen in SOHO environments. When the wireless device bandwidth increases for the none 802.11 applications, the path difference will decrease and to be seen even easer.

When the frequency selective fading happens, the performance of the multi-antenna AP is much better than that of the traditional single transmitter-single receiver AP. The traditional AP deals the frequency selective fading with an equalizer. However, as shown in (1.3c), the signal component $s_1(t)$ at frequency f_1 is zero and therefore there is no signal to equalize with. The traditional AP only has two options: either switch to the low data rate mode and using the processing gain to compensate the frequency null, or switch to the other antenna. The trade off of the former option is a slow data rate. The later option does not have the guaranty of absence of the frequency selective fading at the different frequency f_i for the other antenna. At the same time the traditional AP does not take the advantage of the fact that we have a very good reception at frequency f_2.

In contra to the traditional AP, the multi-antenna AP uses (1.1) to compensate any frequency null from the information from the other antenna automatically, and provides an optimum solution for the reception when the frequency selective fading happens.

Fig 1 shows the signal processing structure to realize the algorithm above. Fig 2 shows a possible ASIC implementation of the signal processing structure. This chip can realize an added-on scalable architecture through multi-transceiver.



$$\mathbf{Y} = [y_1, y_2, \ldots y_M]^T$$

$$\mathbf{X} = [x_1, x_2, \ldots x_N]^T$$

Fig. 1
Principle of Spatial Separation

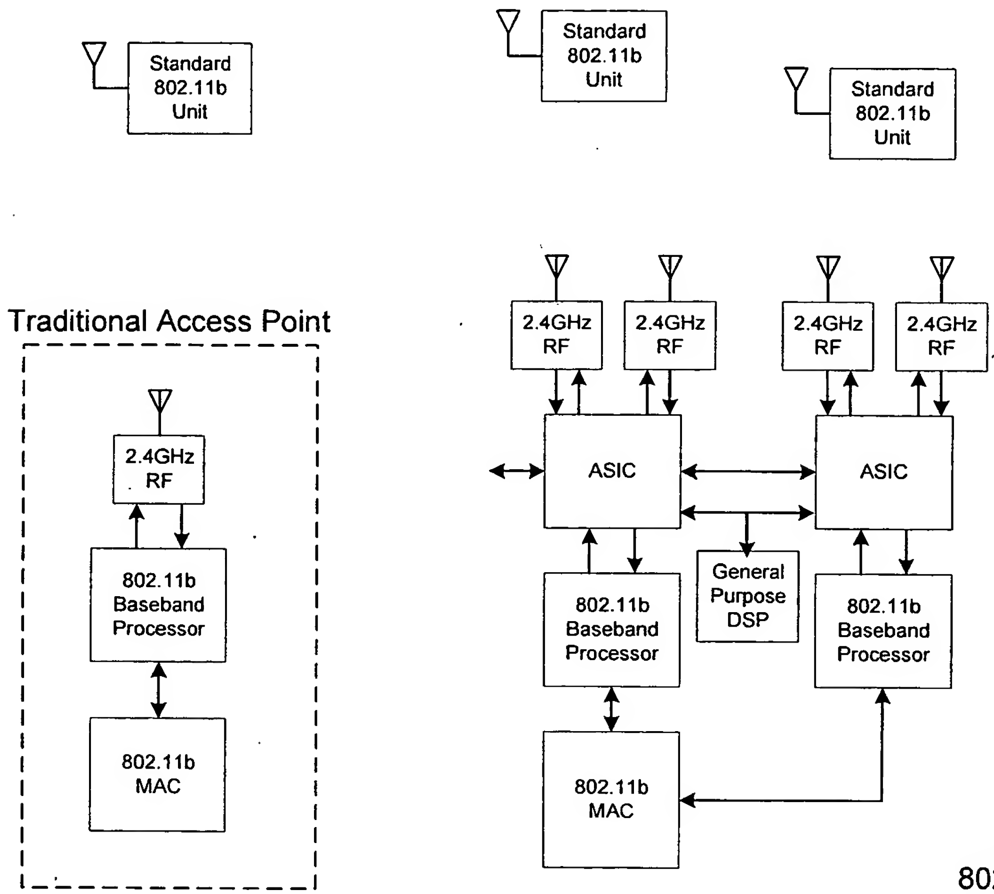


Fig. 2
Configuration for
802.11b enhancement

The 802.11b WLAN Access Point enhancement ASIC can dramatically increase the performance of the 802.11b system. The though-put of 802.11b system under various propagation conditions is shown in Fig. 1. The green area in Fig.1 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 1.

4. 11b^e Functionality

802.11b^e ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It includes the following functions:

General

- Provide a micro-controller interface for software access to internal registers of 11b^e as well as reading/writing of signaling messages
- Generate a set of clocks for all internal modules from a 44MHz master clock

Receive Mode

- Performance A/D conversion for the received I and Q baseband signals.
- Acquiring the timing of the received signal samples relative to the local PN code in PLCP preamble, synchronizing the signal samples to FFT frame.
- Transforming the received signal samples of multiple RF to the frequency domain using FFT.
- Using the known FFT of preamble to estimate the RF channels.
- Separate the signals according to Eq. 1.1
- Reconstruct the received signal in the time domain.
- Convert recovered signal to the analogy form and send out to a standard 802.11b DSSS receiver for decoding.

Transmit Mode

- Framing of the information bit stream to be transmitted
- Symbol mapping/encoding of the bits in a transmit frame
- Scrambler the transmitted data to be transmitted
- Modulating these symbols with Baker or CCK codes necessary for spreading the spectrum of the transmitted data
- Pre-equalize the generated waveforms in frequency domain.
- Make D/A conversion

5. Brief Specification of 802.11b DSSS

This section briefly overviews Direct Sequence Spread Spectrum (DSSS) physical layer.

5.1 802.11b Physical Layer Specification

The following paragraph specifies the High Rate extension of the PHY for the Direct Sequence Spread Spectrum (DSSS) system known as the High Rate PHY for the 2.4GHz band designated for ISM applications. 802.11b DSSS system builds on the data rate capabilities, as described in IEEE Std 802.11, 1999 Edition, to provide 5.5 Mbit/s and 11 Mbit/s payload data rates in addition to the 1 Mbps and 2 Mbps rates. To provide the higher rates, 8-chip complementary code keying (CCK) is employed as the modulation scheme. The chipping rate is 11 MHz, which is the same as the DSSS system described in IEEE Std 802.11, 1999 Edition, thus providing the same occupied channel bandwidth. The basic new capability of High Rate Direct Sequence Spread Spectrum (HR/DSSS) uses the same PLCP preamble and header as the DSSS PHY, so both PHYs can co-exist in the same BSS and can use the rate switching mechanism as provided. In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the radio frequency LAN system to be improved as technology allows the implementation of these options to become cost effective. An optional mode replacing the CCK modulation with packet binary convolutional coding (HR/DSSS/PBCC) is provided. The key parameters of this interface, most relevant to, are listed in the Table 1.

Table 1. Summary of 802.11b Specification

Parameter	Specification
Access Protocol	CSMA/CA (Carrier-sense Multiple Access with Collision Avoidance)
Duplexing method	Time Division Duplex (TDD)
Modulation	BPSK / QPSK/CCK/PBCC
Error Correction	Rate ½ K=7 Convolutional Code

Parameter	Specification
	for PBCC
Spreading	Baker
Chip Rate	11 Mcps
Frame length	Various
Processing Gains	11 at 1,2 Mbps
Bearer Rates	1, 2, 5.5 11 Mbps
High Rate Mode	CCK,PBCC

5.1.1 Frame Structure

The following figure shows the frame structure of 802.11b DSSS physical layer. Figure 4 shows the format for the interoperable (long) PPDU, including the High Rate PLCP preamble, the High Rate PLCP header, and the PSDU. The PLCP preamble contains the following fields: synchronization (Sync) and start frame delimiter (SFD). The PLCP header contains the following fields: signaling (SIGNAL), service (SERVICE), length (LENGTH), and CCITT CRC-16. Each of these fields is described in detail in 18.2.3. The format for the PPDU, including the long High Rate PLCP preamble, the long High Rate PLCP header, and the PSDU, do not differ from IEEE Std 802.11, 1999 Edition for 1Mbit/s and 2 Mbit/s.

The only exceptions are

a) The encoding of the rate in the SIGNAL field;

b) The use of a bit in the SERVICE field to resolve an ambiguity in PSDU length in octets, when the length is expressed in whole microseconds;

c) The use of a bit in the SERVICE field to indicate if the optional PBCC mode is being used;

d) The use of a bit in the SERVICE field to indicate that the transit frequency and bit clocks are locked.

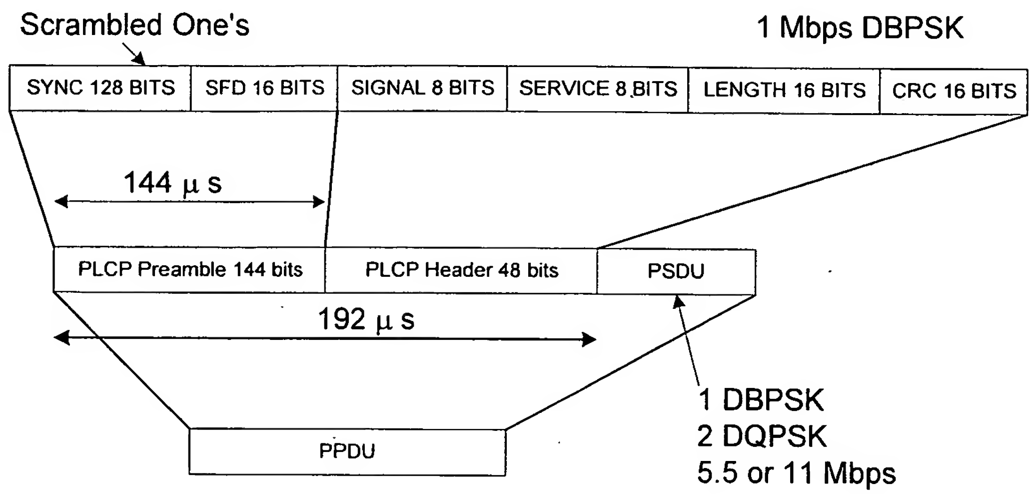


Fig. 4 Long PLCP PPDU format

6. 11b^e ASIC Blocks, Interfaces and Their Functionality

The internal block diagram of 11b^e ASIC is shown in Figure 5. 11b^e ASIC consists of the following major functional blocks and interfaces:

- Clock Generator
- SDRAM Buffer Interface Address Generator
- Three 1024-point FFT/IFFT switch able blocks
- Separation Matrix Multiplier
- On Chip Parameter Memory Bank
- Inter-chip Data Exchange Interface
- DSP Interface
- Preamble Acquisition Module
- Four 6bit A/D at 22MHz
- Four 8bit D/A at 44MHz

DRAFT

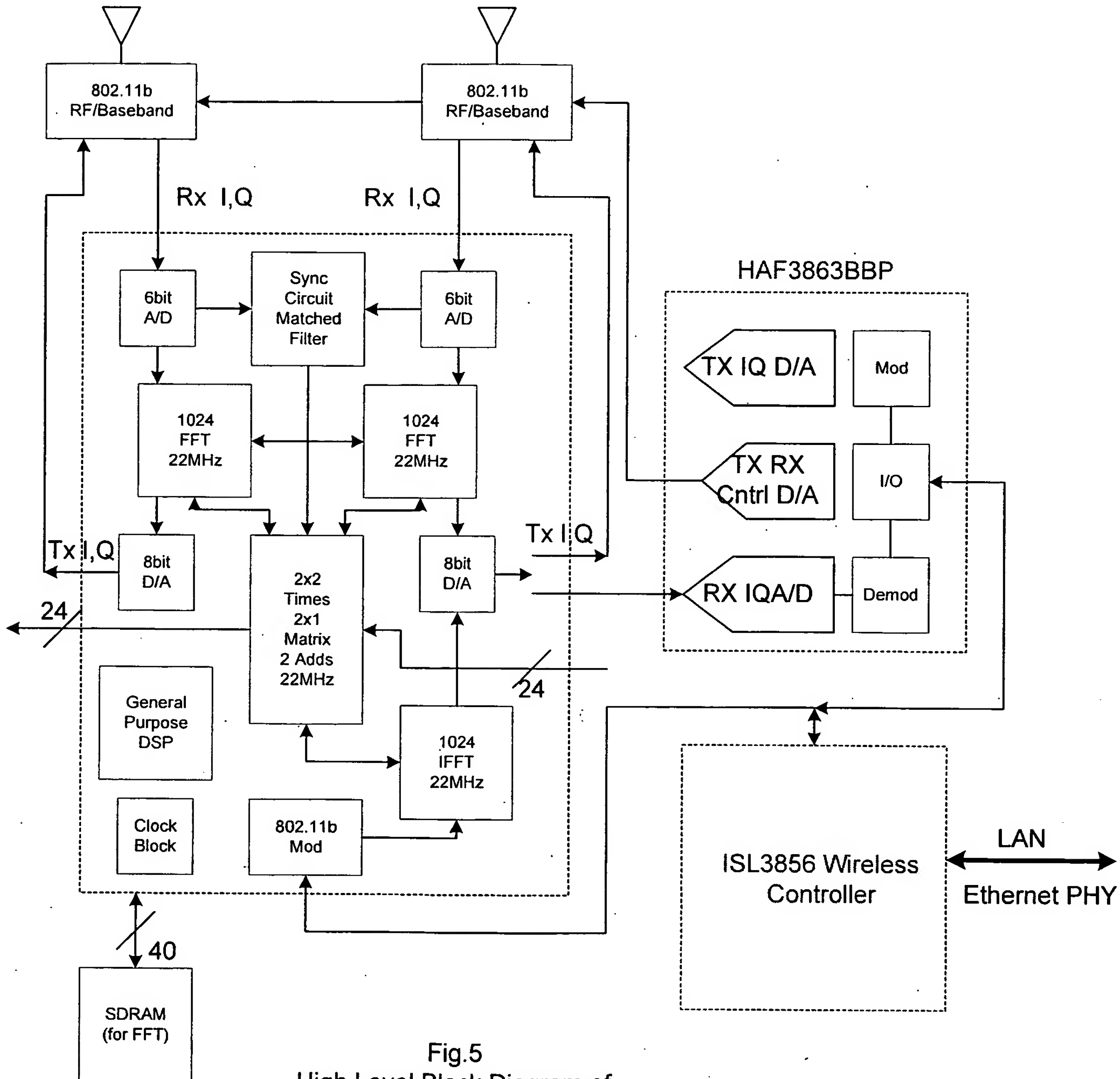


Fig.5
High Level Block Diagram of
$11b^e$ ASIC

6.1 Clock Generator

This module provides all necessary clocks and control signals for other modules of $11b^e$. The key features of this module are described below.

6.1.1 FFT and IFFT Module Clock

The clock generator provides FFT/IFFT modules for the system clock of FFT operation. The system clock cycles for each FFT frame are calculated as the following:

number of passes = ceiling[($\log_2$points)/2]

= 5

number of clock cycles per pass = 14 + points + ceiling[$\log_2$(twiddlewidth)]

= 14 + 1024 + 4 = 1042

number of clock cycles per frame = number of passes * number of clock cycles per pass

= 5210

The minimum clock speed for the FFT/IFFT module with 18% safety margin is:

Clock Rate = 5210/1024*22MHz*118% = 132MHz

The clock rate 132MHz is 3 multiple of the basic clock rate 44MHz. The clock rate 132MHz is generated by using PLL to locked on the system clock 44MHz. The interactions and coordination between the FFT Input SDRAM Buffer and FFT modules is done through a third sub-module, the Arbiter.

6.1.2 FFT Start Frame Timing Control

The FFT start frame timing control signal is provided by the Preamble Acquisition Module. This signal indicates the start data position pointer in FFT Input SDRAM Buffer.

6.1.3 Separation Multiplier Start Timing Control

The clock generator module also provides Separation Multiplier Start Timing Control.

6.2 SDRAM Buffer Interface Address Generator

The interface either uses a general purpose DSP or a configurable interface logic. It still is an open question.

6.3 1024-point FFT/IFFT switch able blocks

There are three 1024-point FFT blocks operating at 130MHz system clock. The blocks can be switched between FFT and IFFT. The input real and imaginary data are 8 bit.

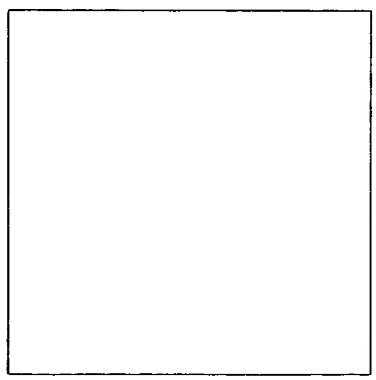


Fig 4 Separation Matrix Multiplier

6.4 Separation Matrix Multiplier

This module essentially perform the following operation at 22MHz when is in receiving mode

$$x = b_1 * y_1 + b_2 * y_2 + x_0$$

where b_1 and b_2 are calculated equalization coefficients; x_0 is the adjacent ASIC recovered signal; y_1 and y_2 are two received data from the current ASIC two baseband channels; x is the

recovered signal. All of them are complex numbers. The operations are 2 complex multiplications and 2 complex additions. The resolution of b_1, b_2, x_0, y_1, y_2, x are 12 bits.

This module perform the following operation at 22MHz when is in transmitting mode

$$T_1 = b_1 * x_t, \qquad T_2 = b_2 * x_t,$$

where b_1 and b_2 are calculated pre-equalization coefficients; x_t is the to-be transmitted signal; T_1 and T_2 are two baseband signals to responding antenna;

6.5 On Chip Parameter Memory Bank

The coefficients b_1, b_2 are the estimated channel equalization parameters for a particular 802.11b station. The on-chip parameter memory bank holds 2*1024 complex parameters for each 802.11b station. If there are 10 such stations to handle, the size of memory bank is 2*2*1024*12*10 = 491520 bits. The on-chip parameter memory bank is supposed to be SRAM.

6.6 Inter-chip Data Exchange Interface

The interface is designed to transfer the data y_0 from the adjacent ASIC and to transfer y_0 the next ASIC.

6.7 DSP Interface

The DSP interface will depends on the general purpose DSP we have chosen.

6.8 Preamble Acquisition Module

The acquisition block performs the initial preamble PN code timing acquisition in the receiver. The processing in this block is based on performing a set of matched filtering operations. This approach is adopted primarily to provide a fast acquisition mechanism.

The matched filtering operation is performed by four 16 chip matched filters, providing a filter that is matched to any 64 chip complex sequence. The input to the matched filter is the stream of received samples at twice the chip rate. Thus, the timing accuracy provided by the Acquisition block is of the order of ¼ of a chip duration.

The block diagram of the matched filter structure is shown in Figure 6.

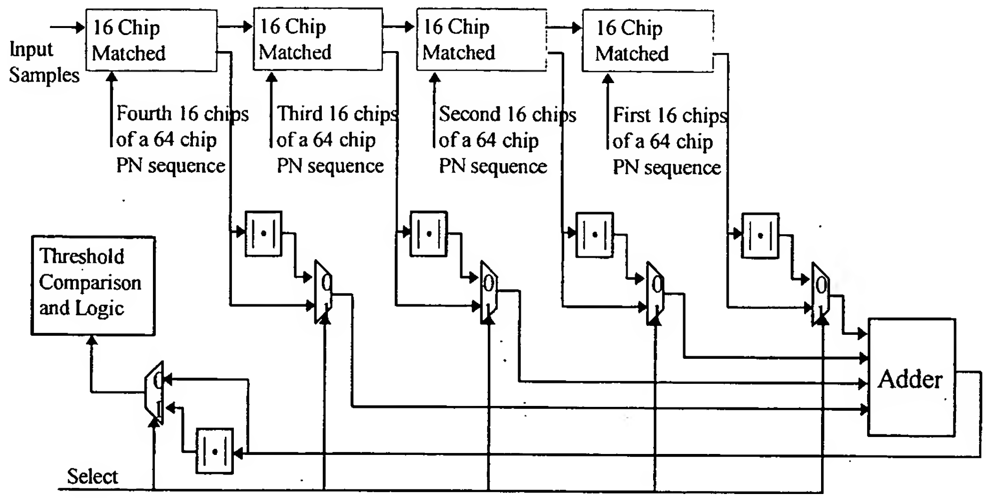


Figure 6. Block Diagram of the Preamble Acquisition Module.

6.9 Four 6bit A/D at 22MHz

There are four 6bit 22MHz A/D in the ASIC. Each baseband signal will need 2 A/Ds (I and Q) to convert it to digital signals.

6.10 Four 8bit D/A at 44MHz

There are four 8bit 44MHz D/A in the ASIC. Each RF path needs 2 D/As (I and Q) to transmit signal to the modulater.

6.10.1 DC Offset Estimation

To estimate the DC value of the signal plus interference we simply low pass filter the received I/Q samples over the entire received frame. The resulting filter output is then subtracted from the I/Q samples. The low-pass filter is a single pole IIR filter of the type:

$$y_k = (1-\alpha)y_{k-1}+\alpha\, x_k$$

where k is the sample index.

6.10.1.1 DC Offset Correction

The estimated offset values in the I and Q paths may be fed back to the ADC outputs to cancel out the offsets from the analog portion of the system. This will be accomplished via a pair of adders immediately following the ADCs, as shown in Figure 7.

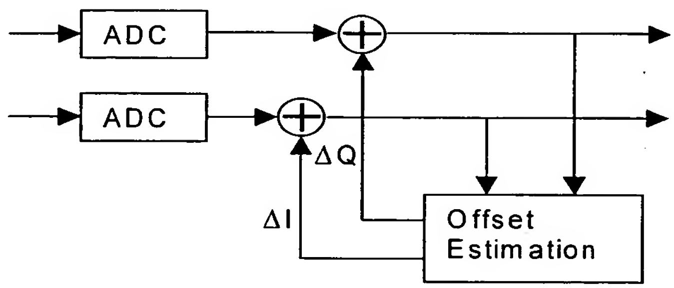


Figure 7. DC Offset Correction.

The offset values will be represented by 5 bit words. This will allow us to correct offsets of less than 7% of the full amplitude swing in the received signal.

7. Operating Procedures

This section describes some of the system operation procedures that rely on explicit support from 11b. More specifically, the portion of system operations that deals with the physical layer aspect of preamble acquisition and connection enhancement are described below.

7.1 Operation Philosophy

The intention of 802.11b WLAN Access Point enhancement is to realize an added-on scalable architecture through multi-transceiver to dramatically increase the performance of the 802.11b system. The projected though-put of 802.11b system under various propagation conditions is shown in Fig. 8. The green area in Fig.8 represents the range and data rate of a typical 802.11b system under such conditions. The performance of 802.11b WLAN Access Point can be greatly improved through multi-antenna reception as shown in Fig. 8. The enhanced receiver portion and the standard receiver will operate simultaneously. When a STA is the green, the communication between AP and STA through the standard 802.11b chip set as long as the AP satisfies with the link through-put. Whenever the STA in the red area or in low data rate green area due to the poor reception or the distance from AP, the enhancement portion can kick in, estimate the channel using the frame of data which the standard 802.11b chip set can not decode on, transfer the data mainly under the mode **point coordination function (PCF).**

The PCF provides contention-free frame transfer. The PC shall reside in the AP. It is an option for an AP to be able to become the PC. All STAs inherently obey the medium access rules of the PCF, because these rules are based on the DCF, and they set their NAV at the beginning of each CFP. The operating characteristics of the PCF are such that all STAs are able to operate properly in the presence of a BSS in which a PC is operating, and, if associated with a point-coordinated BSS, are able to receive all frames sent under PCF control. It is also an option for a STA to be able to respond to a contention-free poll (CF-Poll) received from a PC. A STA that is able to respond to CF-Polls is referred to as being CF-Pollable, and may request to be polled by an active PC. CF-Pollable STAs and the PC do not use RTS/CTS in the CFP. When polled by the PC, a CF-Pollable STA may transmit only one MPDU, which can be to any destination (not just to the PC), and may "piggyback" the acknowledgment of a frame received from the PC using particular data frame subtypes for this transmission. If the data frame is not in turn acknowledged, the CF-Pollable STA shall not retransmit the frame unless it is polled again by the PC, or it decides to retransmit during the CP. If the addressed recipient of a CF transmission is not CF-Pollable, that STA acknowledges the transmission using the DCF acknowl-edgment rules, and the PC retains control of the medium. A PC may use contention-free frame transfer solely for delivery of frames to STAs, and never to poll non-CF-Pollable STAs.

7.2 Preamble Acquisition

Preamble acquisition is performed by the ASIC to line up the FFT frame with the incoming data stream. After the preamble acquisition, the FFT frame in the SYNC of the preamble will provide the channel estimation of the following separation and combining.

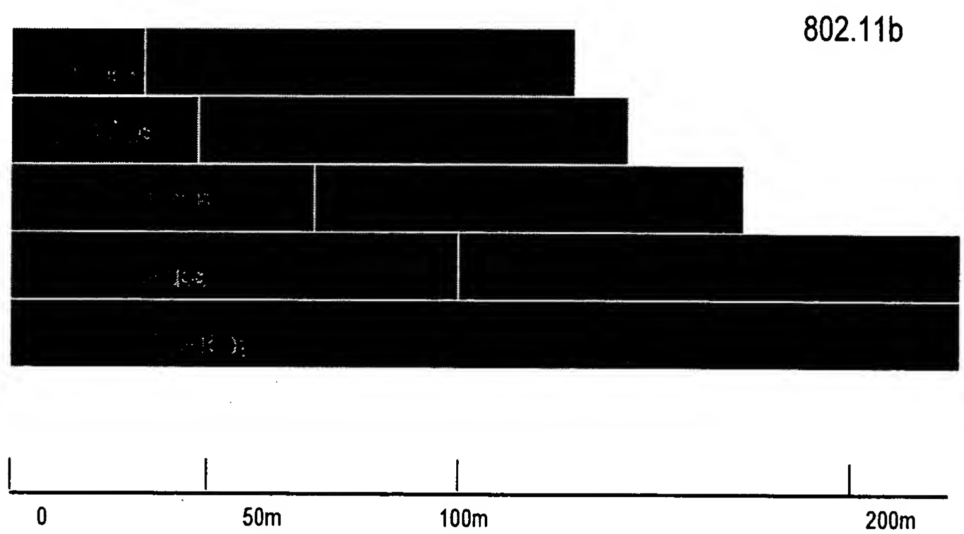


Fig. 8
802.11b enhancement

8. Issues

FFT introduced Delays greater than the mandatory delay SIFS

DCF Mode vs PCF Mode

The SNR Lose due to the Extra D/A and A/D Process

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Multi-Antenna Technology for 802.11 WLANs

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Contents

Executive Summary

Today, people seek out information on the Internet. And tomorrow, information will seek out people using the Internet. One of the enabling technologies for this is a global wireless connection starting with a wireless local area network (WLAN). Historically, the WLANs were viewed as a niche market with proprietary protocols, high costs, and unrealized performance. With the adoption of IEEE 802.11 standards, WLANs now offer a viable alternative to wired LANs, as evident with the explosive growth over the past year. Both large and small companies have or plan to offer solutions based on IEEE 802.11b (WiFi^{TM}), 802.11a and 802.11g. For wide spread adoption, issues in the form of security, higher speeds, and increased radius of operation will need to be addressed. In this paper, Epogy Communications, Inc. describes a new scalable technology, (11b^{e}), utilizing multiple antennas. What distinguishes this technology from other multi-antenna techniques is the simultaneous utilization of all the antennas for transmission rather than selecting the best one antenna. The result is a dramatic improvement in both performance and security. The technology is capable of supporting IEEE 802.11 standards and extends the higher speed range by 10X. Used in conjunction by the access point and mobile terminal, the 11b^{e} technology would enable users to achieve speeds greater than 100 Mbps. However, the main feature of 11b^{e} is the ability to provide security beyond encryption through energy modulation. This new technology provides enhanced security depending on the adopter's preference by not only encrypting the data but by concentrating and selectively reducing the energy so that the transmitted data is indistinguishable from noise.

WLAN Overview

Today's Internet is very different than what it was before; we now view the Internet as a utility, which distributes the flow of information. Much like the water or electric utilities, the Internet is available in almost every school, home and office. It is the fastest growing global information and communications medium with connections available most anywhere. Today people seek out information on the Internet. And tomorrow information will seek out people using the Internet. How will this information reach you, without you having to reach it? The Internet will become wireless, and information will reach you via your cell phone, PDA or laptop. One of the enabling technologies for this global wireless electronic blanket is wireless Ethernet, specified by the Institute of Electronics and Electrical Engineering (IEEE).

Wireless local area network (WLAN) is a communications system that either replaces traditional wired LAN or extends its access beyond the limitations of physical wires. Historically, WLAN was viewed as a niche market for specialized applications like inventory or shipment tracking. Users were limited in throughput, radius, or interoperability with wired LANs due to proprietary protocols.

The adoption of 802.11 standards made possible increased speeds, interoperability between systems, and cost reductions that made WLAN a feasible alternative. Companies like Lucent, Intersil, Cisco, 3COM, Texas Instruments, Microsoft, and Intel have or have announced products supporting the IEEE 802.11 standards. The 802.11 standards define the physical layer (PHY) and media access control layer (MAC); since these layers are based on 802 Ethernet protocol and CSMA/CA shared media techniques, any LAN application, network operating system, or protocol (such as TCP/IP) will run on a 802.11 compliant WLAN.

The WLAN market is comprised of several technologies all competing with different techniques and performance characteristics.

- HomeRF and Home Rf 2.0 (WBFH)
- IEEE 802.11b (DSSS)
- IEEE 802.11a (OFDM)
- IEEE 802.11g
- HiperLAN/2
- MMAC

At the moment, the focus of the standard is on ether the 2.4 GHz band known as 802.11b or the 5 GHz band known as 802.11a. The supported data rates are up to 11 Mbps for 802.11b and are up to 54 Mbps for 802.11a. Products which conform to the 802.11b spec will in most cases work together and interoperate with ease. Essentially, the 802.11b or 11a standard provides open, asynchronous networking that requires a distributed control function.

Much like base stations for cellular technology, WLANs use the Access Point (AP) to provide wireless access to mobile terminals (MTs) or other devices in the network. AP is

a cheap version of the base station for cellular technology and plays a very important role in WLAN. These APs are either connected to other APs, to other wired networks such as Ethernet, or connected to a broadband access medium such as DSL, cable, T1, etc.

IEEE 802.11b

The IEEE 802.11b operates in the unlicensed 2.4 GHz band. This standard permits two (2) distinctive types of transmission for data, Frequency Hopping Spread Spectrum (FHSS) and Direct Sequencing Spread Spectrum (DSSS). With the number of products and companies supporting DSSS, it has become the predominate standard for IEEE 802.11b. A raw data rate of 11 Mbps, 5.5 Mbps, 2 Mbps, or 1 Mbps is specified with a range of 100 meters.

Conventional configurations include single carrier, single receiver (Rx) and single transmitter (Tx) deploying a single omni-directional or dual dipole antenna. This is a simple and low cost solution.

802.11b is the predominate solution available on the market today. Since lower cost RF components may be used to achieve the requirements of 802.11b, the system cost has contributed to rapid growth.

Fundamental wireless channel impairments such as multipath (delay spread, temporal and frequency fading), interference, and noise greatly reduce the radius of the system. In most indoor environments, the 11 Mbps data rate is not achievable at 50 meters.

IEEE 802.11a

For higher speeds, companies are looking at IEEE 802.11a with 54 Mbps data rate. 802.11a uses a technique called Orthogonal Frequency Division Multiplexing (OFDM). OFDM sends multiple data streams simultaneously over separate radio signals in the less congested 5 GHz radio band, which has three (3) times the available spectrum. However, as the number of devices utilizing this band increases, congestion will also become an issue.

Although 802.11a offers a high data rate of 54 Mbps, a fundamental difference between 2.4 GHz and 5Ghz is the transmission range and corresponding coverage area. All things being equal, a higher frequency band will transmit a signal a shorter distance than a lower frequency band. The actual range at 54 Mbps in many instances may be less than 20 meters. This is of particular significance when considering the number of access points (APs) required for a similar area of coverage using 802.11a compared to 802.11b. Figure 1 shows the data rates and their typical coverage range for 802.11b and 802.11a.

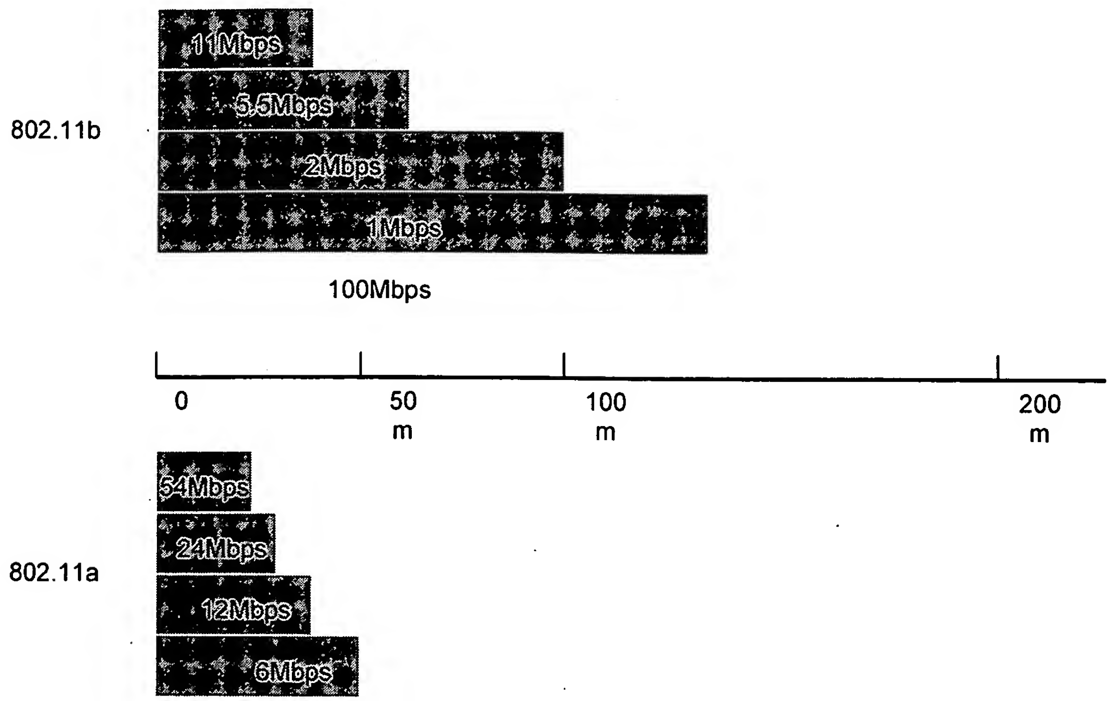

Figure 1:
Performance Comparison Chart of 802.11b and 802.11a

Although numerous companies have announced 802.11a products, only a few have made it to market. Typically, costs are higher due to the more sensitive RF components required. However, costs should decrease as more products make it to market.

Barriers

Interference/Noise

Given the high cost of licensed spectrum, typical WLAN systems utilize either the 2.4 GHz or 5 GHz unlicensed (free) spectrum. As such, other devices and technology like microwave ovens, Bluetooth, satellite systems, and proprietary applications utilizing these unlicensed bands has created an overcrowding situation that will only get worse. A fundamental concern for all WLAN is the interference and noise between devices operating within the same spectrum.

Interference and noise may be viewed in two (2) types; in-band interference and out-of-band interference. Out-of-band interference or noise may be filtered out using the analog section of the receiver. In-band interference would include such time-varying impairments as multiple access interference and multipath conditions. Because the transmitted signal may take multiple paths in reaching the receiver, signal processing is required to address the delay spread, temporal and frequency fading.

Generally speaking, as the noise and interference increases the decipherable signal radius decreases. As a result, additional APs are required to complete coverage for a given area increasing costs and contributing to more interference.

Later in the paper, we will describe a multi-antenna approach that reduces those effects of multipath, interference, and noise through a technique called adaptive signal separation processing.

Security

In a recent survey sponsored by Microsoft, security was the primary issue concerning companies implementing WLANs. The 802.11 standards address the issue in a couple of ways: Extended Service Set ID (ESSID) and Wired Equivalent Privacy (WEP). For ESSID, all mobile units associate themselves with an AP. This type of protection is limited since some products allow the mobile unit to attach to any AP, while others allow the user to browse and dynamically attach to a network.

WEP is a shared-key encryption mechanism option under 802.1 that employees either a 40-bit or 128-bit encryption using the RC4 algorithm. Unfortunately, many vendors have only just begun to implement this feature and it still relies on manual key distribution.

Security architectures typically provide a framework for authentication, encryption, message integrity, and key distribution. As this paper will describe, additional security may be possible by modulating the signal's energy level so that the intercepted signal may be undecipherable to noise.

11b^e Enhancements

Security, increased areas of operation (radius) and higher speeds are three (3) of the main barriers facing WLANs. Our mission starts with using the algorithms to enhance the performance of WLAN 802.11b network AP. The enhancement is named as 11b^e, it intends to be used in the WLAN 802.11b AP with multiple antennas, RF receivers and transmitters. 11b^e serves as a scalable signal processing engine for all functions of radius and speed enhancement in the WLAN 802.11b physical layer. The hardware and software changes for the enhancement are only limited in the APs. The mobile terminals will be standard 802.11b devices. With limited modification, the technology can be also applied to WLAN 802.11a and Wireless WAN 802.16.

Operation Principles

The 802.11b^e ASIC will implement the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be understood as a Multi Inputs Multi Outputs (MIMO) system or Single Input Multi Outputs (SIMO) system. Figure 2 compares the typical RF reception signal shown as SISO (Single Input Single Output) to that of the enhanced SIMO AP. The curves under these reception methods are the received signal levels and the dashed lines are the would-be designed

sensitivity level of the receivers. We can see the reception is greatly improved by the multi-antenna AP. The theory of the operation may be found in the Appendix.

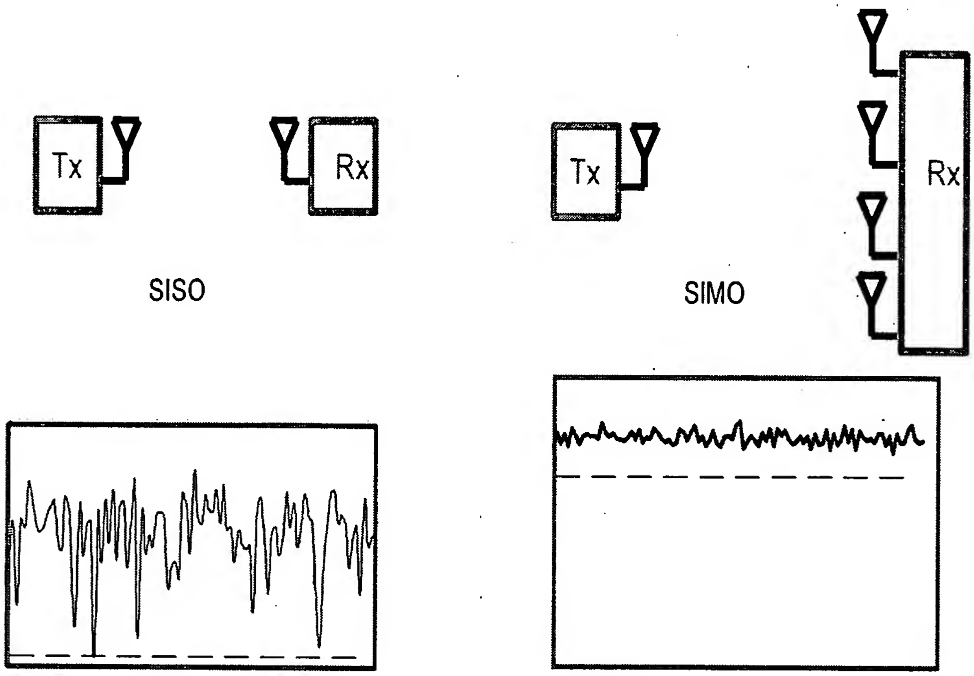

Figure 2:
SISO and SIMO Comparison

*Advantages of 11b^e^*

In contrast to the traditional AP or multi-antenna AP that receives the signal on the best single antenna, the multi-antenna AP described here optimally combines all energy available from the antenna, equalizes them, and provides the best demodulation possible to decode the signals. This multi-antenna AP has several advantages over the traditional AP.

a. Increasing Covering Radius

The transmitted and received power is M times stronger than that of the traditional single transmitter-single receiver (SISO) AP, where M is the number of antennas. For noise contributed from multipath delays, the enhancement provides a very good method for equalization. The signals after equalization will be at least M times strong than that of the single receiver system. Generally speaking, an M fold-increase of the signal either in transmission or reception would translate to a square root of M fold increase in distance, (see Appendix). Also as shown in the Appendix, the multi-antenna AP automatically compensates any frequency null in the information from the other antenna, and provides an optimum solution for the reception when the frequency selective fading happens.

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b. Increasing High Data Rate Covering Radius

The projected though-put of an 802.11b and 802.11a system under various propagation conditions is shown in Figure 3. The green area represents the typical range and data rate of an 802.11b and 802.11a system under such conditions. The performance of 802.11b WLAN AP can be greatly improved through multi-antenna reception as shown by the orange shaded areas in Figure 3. The 802.11b WLAN Access Point enhancement ASIC can dramatically increase the performance of the 802.11b system.

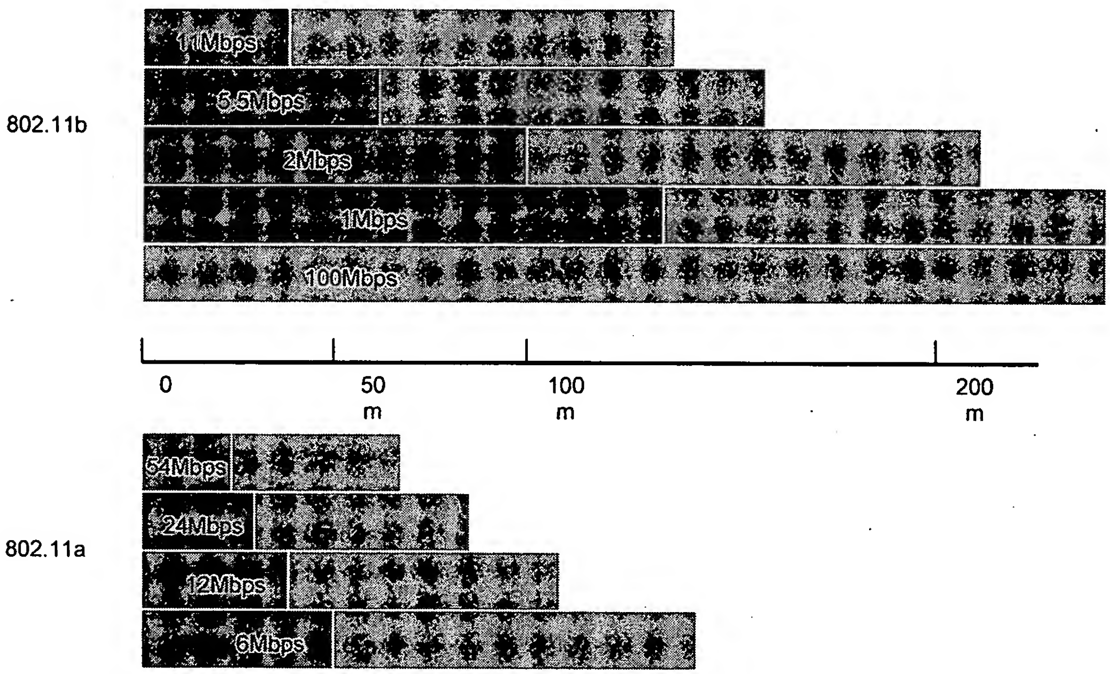


Figure 3:
Performance Enhancement Chart of 802.11b and 802.11a

c. Increasing Security

The emission RF energy from AP is concentrated at the position of the intended mobile terminal (MT), and is significantly less everywhere else. This dramatically decreases the possibility of intercepted by other unwanted intruders.

The RF energy of the signal may be reduced to noise for 95% of the coverage area. Interception would require a device to be positioned similar to the MT; otherwise, the intercepted signal would be undecipherable from noise. This energy modulation security scheme will increase any network's security.

To provide further security, the transmitted data may be encrypted. The encryption scheme used by Epogy utilizes an ever-changing key…____________________.

When used in combination, a total security scheme may be achieved for the transmitted data.

d. A Longer MT's Battery Life

From Figure 2, the multi-antenna AP will experience significantly less fluctuation of the received power as the MT (mobile terminal) moves away from the AP. This would consume less radiated power for the MT to communicate with AP. This will translate to a longer battery life and less interference to the adjacent AP cells.

Architecture of AP Enhancement

The 802.11b WLAN AP enhancement is realized through an added-on scalable multi-transceiver architecture to dramatically increase the performance of the 802.11b system. Figure 4 shows the signal processing structure to realize the algorithm described in the Appendix.

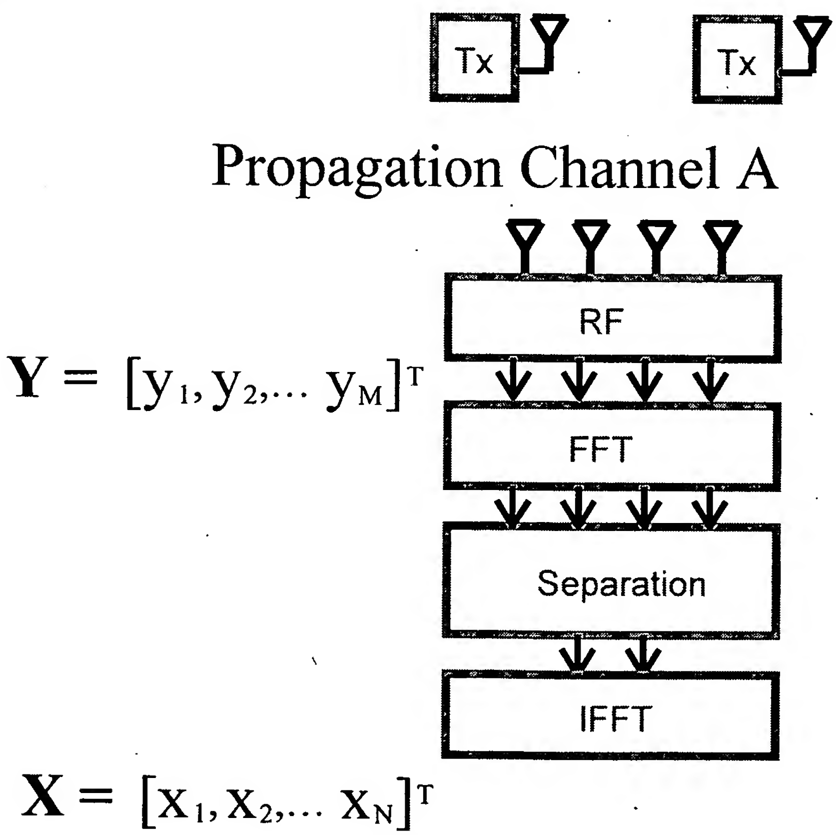


Figure 4:
Spatial Separation Processing Structure

Figure 5 shows a possible ASIC implementation of the signal processing structure. This architecture is flexible should the AP require a higher receiving sensitivity. The number of multi-transceivers can be configured as 2, 4, 6, and so on. The more stages added, the more powerful the AP's performance.

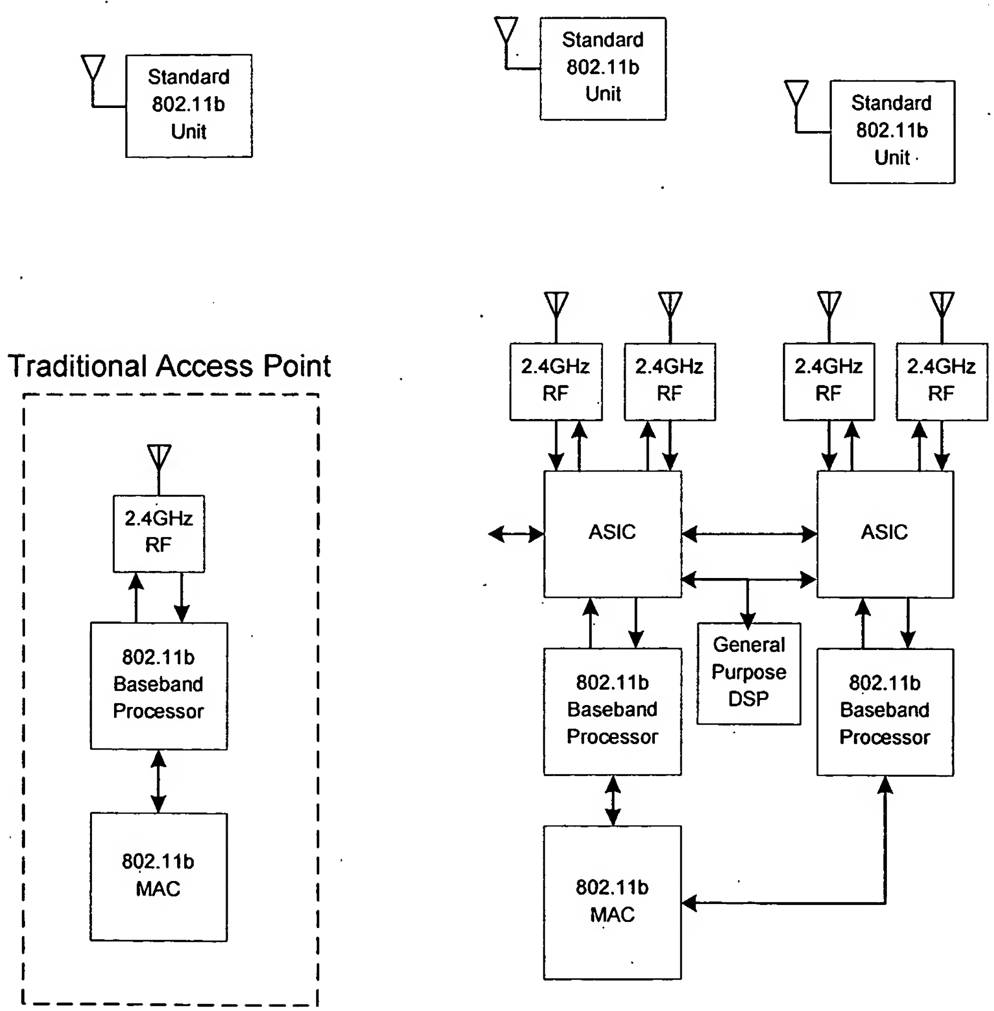
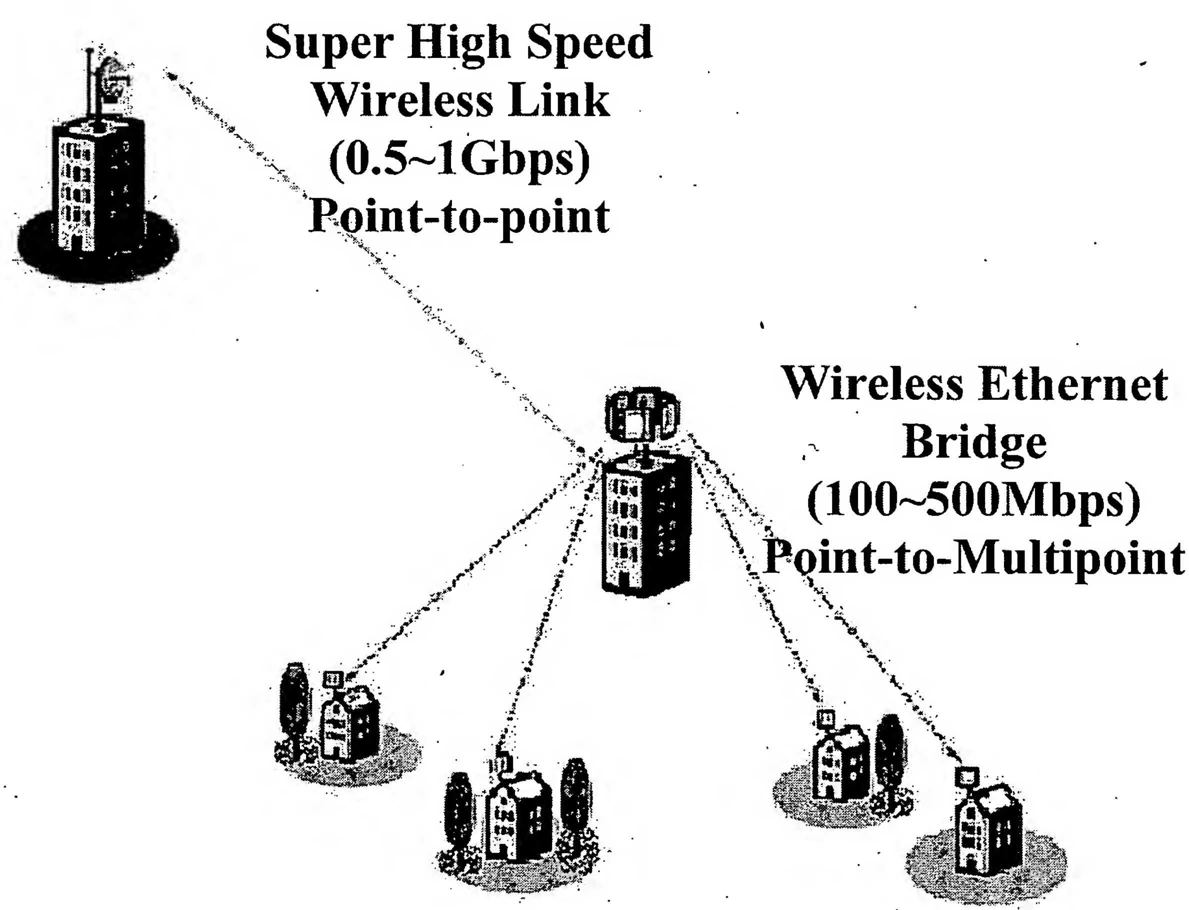


Figure 5:
ASIC Configuration for 802.11b Enhancement

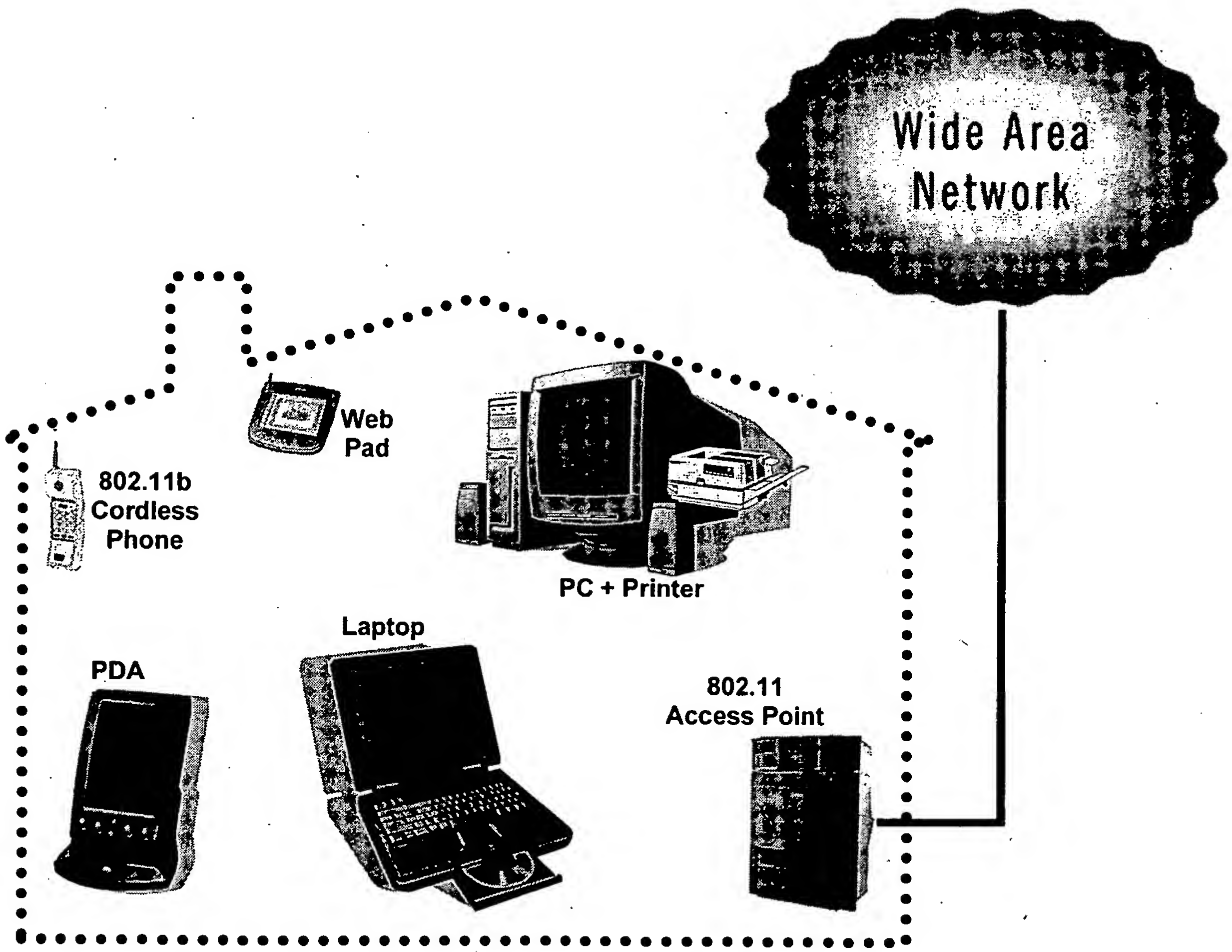
Enhancement Extension

The operation principles of AP enhancement are similar from 802.11b WLAN to 802.16 WAN and 802.11a WLAN. The 802.11b WLAN AP enhancement ASIC can be easily designed to comply with the recently finalized version of 802.16 Wireless WAN. 802.16 Wireless WAN may be considered a wireless solution to the problem of last mile. With some modification, the 802.11b WLAN AP enhancement ASIC can be used for 802.11a WLAN, which seems to be in more of a need for a radius enhancement.



Residential Extension

The residential segment of this market has undergone a revolution with the introduction of the high-speed Internet access into homes. Now more than ever, homes are being networked to support personal computers (PCs), laptop computers, printers, personal data assistants (PDAs), and shared Internet access. The ease of installation and the flexibility to move and relocate a WLAN will see a high percentage of home networking installations go wireless. Many have discussed the possibility of a future convergence to a single access point capable of data, voice, and video.



Summary

As the Internet continues to revolutionize the information flow, high-speed wireless access will be required to access this information from any location. With an ever-increasing number of devices and users, interference, noise, bandwidth, speed, and security will become the main concerns for WLANs. By using the multi-antenna approach described, WLANs would see a dramatic enhancement in performance and security. In an 802.11b WLAN, the higher speed (11 Mbps) range would be increased ten-fold. When used in conjunction by the AP and MT, speeds in excess of 100 Mbps may be achieved. Even if no additional security or encryption is implemented by the WLAN, by concentrating the RF energy at the MT's position, the transmitted signal would appear to be noise and virtually undecipherable everywhere else. The technology is scalable depending on its specific needs. Although the technology presented in this paper offers a new technique in addressing WLAN issues, it may be implemented for any form of wireless communication.

Appendix: 11b^e Operation Principles

802.11b^e ASIC implements the digital signal processing functions required to enhance a single 802.11b connection over a 2.4 GHz RF link. It can be interpreted as a Multi Inputs Multi Outputs (MIMO) system or Single Input Multi Outputs (SIMO) system. Its principle of operation is shown as following:

$$Y = AX + N \quad (1.0)$$

where $\mathbf{X} = [x_1(t), x_2(t), \ldots x_N(t)]^T$ is N signals to be transmitted; $\mathbf{Y} = [y_1(t), y_2(t), \ldots y_M(t)]^T$ is M received signals from RF; $\mathbf{A}$ is the M by N propagation medium mixing matrix; $\mathbf{N} = [n_1(t), n_2(t), \ldots n_M(t)]^T$ is M additive white noises from M receivers. In the time domain, Eq. 1.0 can be considered when there are either short or non-existent multi-path delays. Our existing analog signal separation demonstration is the implementation under such a situation. When short multi-path delay conditions cannot be met, **AX** in (1.0) can be considered either as a convolution operation or as a frequency domain. Since convolution operations are usually complicated, we will concentrate our effort in the frequency domain cases.

The least squares solution to (1.0) is:

$$X = (A^*A)^{-1} A^*Y \quad (1.1)$$

Where the channel mixing matrix **A** can be either blindly estimated, as what was done in the analog implementation using HJ networks with Bartley matrix, or characterized by using the training signal which is the preamble of the Physical Layer Convergence Protocol (PLCP) in 820.11b.

The performance enhancement of the multi-antenna (SIMO) Access Point (AP) is beneficial from two aspects:

1). The transmitted and received power is M times larger than the traditional single transmitter-single receiver (SISO) AP. For noise from multipath delays, the enhancement provides a very good way of equalization. The signals after equalization will be at least M times strong than the single receiver system. If $M = 4$, the increase in the received power will be translated to a 2x increase in range, as shown in Eq. 1.2.

$$P = M^*p_0^*(2^*r)^{-2} = p_0^*r^{-2} \quad (1.2)$$

Where P is the power received by $M = 4$ receivers, p_0 is the power received at a unit distance from the radiator.

2). When the multipath delays are long enough, the multipath effect can produce a frequency selective fading. The frequency selective fading effect means that the received

signal $S(t)$ at frequency f_1 --- $s_1(t)$ is much weaker than the received signal $S(t)$ at frequency f_2 --- $s_2(t)$. The effect can be illustrated as following:

$$s_1(t) = e^{-i2\pi f1t} + e^{-i2\pi f1(t+\Delta t)} = e^{-i2\pi f1t}\,(1 + e^{-i2\pi f1\Delta t}) \quad (1.3a)$$
$$s_2(t) = e^{-i2\pi f2t} + e^{-i2\pi f2(t+\Delta t)} = e^{-i2\pi f2t}\,(1 + e^{-i2\pi f2\Delta t}) \quad (1.3b)$$

where $S(t)$ is the resulted signal from the combination of the two paths, $s_1(t)$ and $s_2(t)$, which are the frequency components of the signal $S(t)$ at frequency f_1, frequency f_2, respectively. In (1.3a) and (1.3b), the two paths are assumed to have the same amplitude but with a delay difference Δt. To see the frequency selective fading effect, one can let $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$, which translates (1.3a) and (1.3b) to:

$$(1 + e^{-i2\pi f1\Delta t}) = 0 \quad (1.3c)$$
$$(1 + e^{-i2\pi f2\Delta t}) = 2 \quad (1.3c)$$

For the smallest possible Δt to produce the effect, $s_1(t)=0$ and $s_2(t)= 2e^{-i2\pi f2t}$.

$$f_1\Delta t = 1/2 \quad (1.3e)$$
$$f_2\Delta t = 1 \quad (1.3f)$$

Therefore

$$(f_2 - f_1) = 1/(2\Delta t\,) \quad (1.3g).$$

For 802.11b systems, the bandwidth is 22MHz. If f_2 and f_1 are two frequency points in that band, one can see for $f_2 - f_1 = 11\text{MHz}$, $\Delta t = 46\text{ns}$. This means that delay is as small as 46ns, whereby certain conditions can produce a severe frequency selective fading. The delay difference of 46ns can be translated to a path difference of 14 meters, which can be easily seen in SOHO environments. When the wireless device bandwidth continues to increase for the non-802.11 applications, the path difference would further decrease and making it easier to see.

When the frequency selective fading happens, the performance of the multi-antenna AP is much better than that of the traditional single transmitter-single receiver AP. The traditional AP handles frequency selective fading with an equalizer. However, as shown in (1.3c), the signal component $s_1(t)$ at frequency f_1 is zero and, therefore, there would be a lack of a signal to equalize with. The traditional AP has only two options: either switch to a lower data rate mode, and thereby use the processing gains to compensate the frequency null, or switch to the other antenna. The trade off of the 1st option is a slower data rate. The later option does not guarantee the absence of the frequency selective fading at the different frequency f_i for the other antenna. At the same time the traditional AP does not take the advantage of the fact that we have better reception at frequency f_2.

The multi-antenna AP can use (1.1) to automatically compensate any frequency null in the information from the other antenna, and provides an optimum solution for the reception when the frequency selective fading happens.

EXHIBIT C

WLAN Enhancement ASIC

Operation Mode Constraints

1 Outlines

1.1 Outlines

This document intends to describe the operation constraints when apply EPOGY WLAN enhancement ASIC in the IEEE 802.11b Access Point (AP).

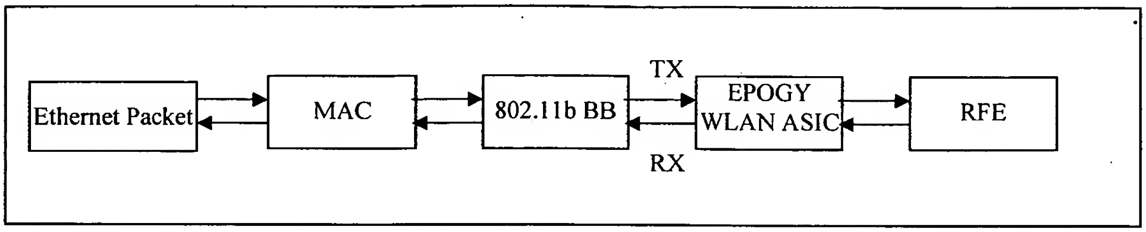
1.2 Revision History:

REV. NO.	DATE	AUTHOR	DESCRIPTION
0.0	01/15/02	Rex H. Shaolin L.	Initial version

[redacted]

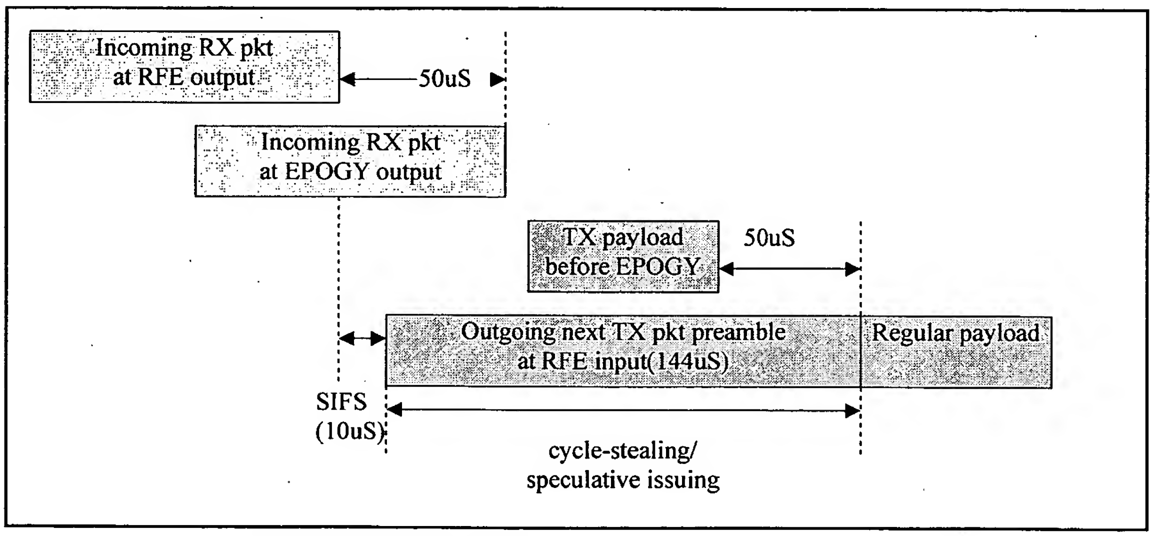
2 Operation Constraints

As shown in Figure 1, an 802.11b transceiver with EPOGY WLAN Enhanced ASIC between the 11b baseband processor and the RFE. Since an average of 50uS is introduced in the RX data path, a special "cycle-stealing" concept has been applied to avoid the violation of IEEE 802.11 SIFS or PIFS timing.



• Figure 1 EPOG WLAN Enhanced 802.11b Transciever

As shown in , SIFS(10uS) after the end of previous RX packet, a pre-stored(?? Can we) 144us preamble is issued before the previous RX packet is fullu decoded. Therefore the 802.11 SIFS timing can be maintained.



• Figure 2 Cycle-stealing timeline

2.1 Assumptions

To implement the speculative issuing, the following protocol assumptions have to be made:

1) For a short 802.11 frame, the "Destination Address field" (DA) within the incoming RX packet may not be decoded in time for the AP decide to start sending.

2) For a short 802.11 frame, the "Frame Type" within the incoming RX packet may not be decoded in time for the AP decide to start sending.

2.2 Operation mode

The current intended operation mode intended for the EPOGY WLAN enhanced AP is under the Point Coordination Function (PCF). Under the PCF, a contention free period (CFP) is established on the medium. The PCF-capable AP starts the contention free period with a beacon frame, then all the STA can only access the medium after they are "polled" by the AP. In this fashion, the access sequences on the mediums can be easily determined beforehand by the AP. For example, AP-STA1-AP-STA2-AP-STA3-AP-AP-STA4. Note that under this condition, there is no two consecutive STA access on the medium, therefore safe "speculative issung" can be assumed by the AP.

2.3 Constraints

The EPOG WLAN Enhanced ASIC can not operate under the basic DCF (distributed coordination function) mode, since under this mode, there is no pre-defined sequences for the "cycle-stealing" issuing to reference. Although the EPOGY ASIC RX path can be active at all times (parellel to an 11b RX path w/o EPOGY WLAN ASIC delay), the EPOGY ASIC TX path should not be active.

3 Special Considerations

Because of the special "TX wave beaming" capability, the WLAN ASIC helps to transmit TX packet to further recipient(s) at a specific locations instead of all recipients out of regular 802.11b TX range. Special considerations are to taken for the following situations:

3.1 Authentication and Association

Before any STA to associate with an AP, the STA has to authenticate and then associate with the APs by sending out "Authetication" or "association" packets. While these packets are sent by out of (11b regular) range STA to AP in the contention period (CP), apparently the WLAN ASIC enhanced AP can only respond to these far out STA in the following contention-free period (CFP).

It's reasonable that the Expire timers (in terms of multiple of TU==1024 uS) conditions can be satisfied by either a.) AP to treat these requests as high priority, therefore to establish a CFP to respond, or b.) the AP can preset the CFP/CP alternating time ratio to a reasonable range.

Similar scenarios exists in other packets, ex: "Probe request">

3.2 Multiple destination transmission

Beacon frame, broadcast, and multicast are typical packets targeted for multiple destinations (STAs).

For multiple targets spreading across different directions, "multiple sending of the same payloads" method may be required, i.e. a typical 802.11b (w/o WLAN IC) multicasting transmission first to all the in range targets, then followed by location specified (w/ WLAN enhaced ASIC) sending to the out of regular 11b range targets.

For multiple targets in a concentrated area, the associated EQ coefficient array might be combined to form a new hybrid sending EQ coefficients, therefore to cover a specific direction/locality with one packet transmission. However, the EQ coefficient array associated with each STA need to be stored, and an efficient algorithm to determine the new hybrid EQ coefficient array is still to be determined ...

EXHIBIT D

10285

ATTORNEY CLIENT PRIVILEGED AND CONFIDENTIAL

To: **Homer Chang**
President and CEO
Epogy Communications

From: **J. Nicholas Gross** JNG

Date: Wednesday, February 27, 2002

Re: Invoice for Services Rendered

Greetings Homer.

The enclosed is my invoice for services rendered in connection with various patent matters dating back several months (to October in fact). Please note that we never billed you for anything before.

To make things easier for you, I cut quite a bit of my time except for those hours where I had to travel down to Sunnyvale to meet with you guys in person. Also, the only expenses we are charging you are the actual costs we incurred in filing the provisional application. I hope you will find this very reasonable.

Should you have any questions, please feel free to call me (415) 551 – 8298.

Best regards.

J. Nicholas Gross - Attorney at Law
Suite 240
1385 Mission Street
San Francisco CA 94103

Invoice submitted to:
Homer Chang
1271 Oakmead Parkway
Sunnyvale CA 94085

February 26, 2002

Invoice # 10285

Professional services

		Hrs/Rate	Amount
10/29/01	Conducting prior art search and contemporary product literature review in preparation for meeting concerning multi antenna wireless lan patent filings	2.00 300.00/hr	NO CHARGE
10/31/01	Travel and meeting with Homer Chang and Shaolin Li to discuss potential patent issues, applications, etc.	3.50 300.00/hr	1,050.00
11/6/01	Telephone conference with Bergeson concerning contract issues	0.50 300.00/hr	NO CHARGE
12/21/01	Following up with H Chang concerning application	0.33 300.00/hr	NO CHARGE
1/5/02	Reviewing draft of application for evaluation of patent possibilities	1.50 300.00/hr	NO CHARGE
1/9/02	Review of draft materials on new wireless device; researching effects of document disclosure procedure performed in 2000; travel and meeting with reps from Epogy to discuss IP issues	6.00 300.00/hr	1,800.00

		Hrs/Rate	Amount
1/11/02	Reviewing followup materials from H Chang	0.33 300.00/hr	NO CHARGE
2/12/02	Followup note to Homer C and Telephone conference about requirements for filing provisional and strategies	0.50 300.00/hr	NO CHARGE
2/20/02	Travel and meeting with Epogy personnel to go over IP issues, explain options; reviewing new disclosure	4.50 300.00/hr	1,350.00
2/22/02	Reviewing disclosure for accuracy, content, and preparing in form for provisional filing; Telephone conference with H Chang concerning same	1.00 300.00/hr	300.00
	Assist with preparation of filing provisional application; copy, Express Mail same to Patent Office	2.00 80.00/hr	160.00
2/24/02	Miscellaneous emails, followups, etc., with Homer, Peter Courture, concerning patents and ways to enhance value for Epogy	0.75 300.00/hr	NO CHARGE
	For professional services rendered	22.91	$4,660.00
	Additional charges:		
2/22/02	Provisional application fee plus Express Mail charges		92.45
	Total costs		$92.45
	Total amount of this bill		$4,752.45
	Balance due		$4,752.45

EXHIBIT E

INTELLECTUAL PROPERTY PURCHASE AGREEMENT

This Intellectual Property Purchase Agreement ("Agreement"), effective as of January 15, 2003, is made by and between Epogy Communications, Inc. ("Epogy") having a place of business at 1271 Oakmead Parkway Sunnyvale, CA 94085, and J. Nicholas Gross ("Purchaser"), an individual having a mailing address of 3883 18th Street, San Francisco, California 94114.

RECITALS

A. Whereas Epogy intends to cease business and wind down operations immediately as a result of a lack of continued funding from investors and shareholders;

B. Epogy has certain financial obligations associated with closing its business for which it desires to secure sufficient monies to help pay off such obligations;

C. Epogy owns certain intellectual property assets, including patents, applications, inventions and other know-how detailed below;

D. The intellectual property of Epogy, with very limited exceptions, is primarily in an unrealized, unactualized state requiring a significant additional investment of legal fees and filing costs to develop into protectable form;

E. Epogy's investors, including its shareholders, have been consulted and are unwilling to invest additional fees and costs to sustain, preserve or actualize the value of the intellectual property assets;

F. Epogy's Board of Directors, shareholders and officers believe it is in the best interests of Epogy to dispose of certain assets owned by Epogy, including intellectual property and other assets to secure monies sufficient to pay off any remaining obligations;

G. Epogy has attempted to procure a purchaser of the intellectual property assets over the course of the past year but has been unsuccessful to date;

H. Time is of the essence because Epogy must cease operations immediately, and accordingly Epogy has determined that the nature of the assets to be sold is such that an undue delay associated with conducting an extensive marketing of the assets will diminish the value of such assets, and/or be impractical;

THEREFORE, the parties agree:

1) Definitions. As used in this Agreement:

(a) "Assets" means all of Epogy's right, title, and interest in any Assignment Agreements, Patent Files, Patents, Intellectual Property and Supporting Documentation.

(b) "Assignment Agreements" means any agreements assigning ownership of patents, patent applications and/or other intellectual property from inventors and prior owners to EPOGY, including employment agreements, assignment agreements, purchase agreements, etc.

(b) "Patent Files" means the prosecution histories of the Patents in the United States or foreign patent offices, and any other documents in EPOGY's possession or control that are directly related to prosecution and/or enforcement efforts by EPOGY of the Patents, including but not limited to invention disclosures; drafts of applications for the Patents; prior art; technical, legal and/or expert analyses of any of claims of the Patents; inventor communications pertaining to the Patents; and any third party documents or correspondence relating to claim analyses or prior art to the Patents.

(c) "Patents" means the United States patents and patent applications owned by Epogy and listed on Exhibit A, attached hereto and made a part hereof, and all extensions, renewals, divisions, continuations, reissues, reexaminations, continuations-in-part and foreign counterparts thereof.

(d) "Intellectual Property" means all rights of an individual or entity in, to, or arising out of: (i) any U.S., international or foreign patent or any application therefor and any and all reissues, divisions, continuations, renewals, extensions and continuations-in-part thereof; (ii) inventions (whether patentable or not in any country), invention disclosures, improvements, trade secrets, proprietary information, know-how, technology and technical data; (iii) copyrights, copyright registrations, mask works, mask work registrations, and applications therefor in the U.S. or any foreign country, and all other rights corresponding thereto throughout the world; (iv) moral rights; (v) domain names and domain name registrations; (vi) trademarks and trademark registrations; and (vii) any other proprietary rights anywhere in the world similar to those described in this definition.

(e) "Supporting Documentation" means any materials, in electronic form or otherwise, which relate to any Intellectual Property owned by Epogy, including for example: inventor notebooks, inventor writings/drawings, technical materials, prototypes, and all other technical and organizational documentation associated with Epogy's efforts in designing a wireless LAN ASIC including but not limited to designs, drawings, charts, manuals, material lists, blueprints, formulae, reproductions, written and printed instructions, descriptions, reports, material and equipment specifications, pictures and diagrams, computer print outs, magnetic tapes or disks or similar storage devices as implemented by Epogy.

2) Assignment of the Patents. Upon full payment required by paragraph 6(a), EPOGY will execute the assignment of Exhibit B.

3) Transfer of the assets. Upon full payment required by paragraph 6(a), EPOGY hereby transfers and assigns to Purchaser (or to any designee of Purchaser) the Assets, including all of the Assignment Agreements, Patent Files, Patents, Intellectual Property and Supporting Documentation.

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4) Deliveries. Within ten (10) days or such reasonable time as may be required after payment of the purchase price for the Patents, EPOGY will deliver to Purchaser in accordance with Purchaser's instructions, and Purchaser will notify EPOGY in writing, of receipt and acceptance of:

(a) The Patent Files (including the last known addresses, and if available, telephone and other contact details for the inventors of the Patents); and

(b) The Intellectual Property (including any hard copies and/or electronic versions of invention disclosures, patent applications, drafts of potential patent applications, etc.)

(c) Assignment Agreements (including any original signature materials);

(d) The Supporting Documentation (as noted above)

5) EPOGY Cooperation. After the assignment of paragraph 2, and conditioned upon payment of the purchase price for the Patents, EPOGY will provide reasonable assistance to Purchaser in:

(a) Authorizing any inventors to discuss with Purchaser and its representatives all matters reasonably related to and/or concerning the Patents and Intellectual Property (without regard to any obligations of confidentiality or otherwise that may be owed to EPOGY);

(b) Providing copies to Purchaser of additional files and documents that are relevant to the US issued versions of the Patents and in EPOGY's possession and control within 30 days (including without limitation those relating to conception, reduction to practice, practice, diligence, enforcement, validity, enforceability and interpretation);

(c) Providing letters of instruction and revocations of Powers of Attorney with respect to prosecution counsel for the Patents, and consents to permit such counsel to continue to represent Purchaser (and its successors) in connection with such Patents;

(d) Executing and delivering additional documents which are reasonably required in order to effectuate the assignment accomplished by this Agreement, including without limitation, promptly signing the assignment of Exhibit B and such further documents as may be reasonably necessary with respect to the laws of the U.S. or any other jurisdiction; and

6) Payment.

(a) In full consideration of the Assets and assignments of paragraphs 2 and 3, Purchaser will pay to EPOGY the sum of [redacted]. [redacted] of the forgoing sum shall be before execution of the present Agreement by a check delivered to EPOGY and the balance shall be due and payable upon execution by Epogy of this Agreement and the Assignment documents of Exhibit B. No other sums or royalties shall be due from Purchaser to EPOGY or any other as a result of this Agreement,

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the Assets, the assignments of the Patents, or the conveyance hereunder. Furthermore, in no event shall Purchaser have any liability for any payment of any amounts that may be due to third parties pursuant to any agreement between EPOGY and any third parties as a result of the present Agreement and/or EPOGY's transfer of the Patents.

(b) Payment is due in the United States in United States Dollars.

(c) The payment of paragraph 6(a) is exclusive of any and all value added, withholding, excise and other similar taxes, which are the responsibility of Purchaser.

7) Warranties. Subject to paragraph 8, EPOGY represents and warrants to Purchaser that:

(a) It owns the entire right, title and interest to the Assets, free and clear of any liens or encumbrances.

(b) The Patents shall be assigned and transferred free of any claims, liens and encumbrances.

(c) It possesses the right and power to enter into this Agreement and grant the rights granted herein.

(d) No licenses or covenants not to sue have been or will be granted by EPOGY under the Patents and, to the best of EPOGY's Knowledge, there are no grants of rights under the Patents (including grants to former owners and inventors).

(e) All Patent Files, Assignment Agreements, Intellectual Property, and Supporting Documentation have been or will be delivered to Purchaser.

(f) The names and addresses of inventors provided to Purchaser are true and correct, to the best of EPOGY's Knowledge.

(g) The person(s) signing on behalf of EPOGY have all requisite authority, approval and consent - including from the Board of Directors and any relevant shareholders - to enter this Agreement and the Assignments involved, and to bind EPOGY to the terms involved.

8) Limitations on Warranties.

(a) EPOGY makes no warranties as to the validity or enforceability of any of the Patents.

(b) EPOGY makes no warranties that the practice of any of the Patents does not infringe any third party patents.

(c) Except as set forth in paragraph 7, EPOGY makes no warranties whatsoever, including without limitation warranties of merchantability or fitness for a particular purpose.

9) Limits on Remedies.

(a) EPOGY's liability for any breach of warranty or under any other theory of liability asserted by Purchaser under this agreement shall be limited to a refund of a pro-rata portion of the consideration paid under paragraph 6(a). Under no circumstances shall EPOGY's liability to Purchaser under this section 10(a) exceed, in the aggregate, the amount EPOGY receives under paragraph 6(a).

(b) Any remedy for a breach of warranty or under any other theory of liability arising from this agreement will be unavailable to Purchaser unless Purchaser notifies EPOGY of the breach of warranty or the claim of liability, in writing within three months of the discovery of such breach of warranty or the basis for such liability; provided, however, that the foregoing shall not have the effect of extending any applicable statute of limitations.

11) Limitation of Liability and Agreement to Indemnify

Under no circumstances shall EPOGY be liable for any consequential, special, indirect, punitive, or incidental damages arising under or in connection with this Agreement or Purchaser's ownership or use of the Patents.

12) Limitation of Rights Granted. No rights are granted by EPOGY to Purchaser except as expressly set forth herein.

13) Assignability, Successors and Assigns. Purchaser contemplates the Patents will be assigned to a successor. This Agreement shall inure to the benefit of and be binding on the parties and their successors and assigns.

14) Governing Laws. The validity and interpretation of this Agreement and the rights and duties of the parties shall be governed by the laws of the State of California, without regard to conflicts of laws principles. The state and federal courts of California shall have exclusive jurisdiction to hear any lawsuit between the parties.

15) Confidentiality. EPOGY and Purchaser agree to keep in confidence and not to disclose to any third party the terms and conditions of this Agreement, except to the extent required by statute or regulation or order of a court of competent jurisdiction or as may be required to obtain the bankruptcy court's approval of this Agreement.

16) Counterparts. This Agreement may be executed in duplicates and counterparts, which, taken together, will be deemed and serve as an original. In addition, the parties agree that their authorized representatives may bind them to the terms of this Agreement with signatures exchanged by fax, provided that original signature pages will be substituted for those fax signatures as promptly as reasonably possible, and that each party intends to retain one fully executed original of this Agreement, and each of those duplicate "wet" signature originals will be deemed to be an original of this Agreement.

JG

17) Notifications

(a) Any notice from Purchaser to EPOGY regarding this agreement is to be in writing and directed to:

Homer Chang
President & CEO
1271 Oakmead Parkway
Sunnyvale, CA 94085

(b) Any notice from EPOGY to Purchaser regarding this agreement is to be in writing and directed to:

J. Nicholas Gross
3883 18th Street
San Francisco, CA 94114

18) Entire Agreement. This is the entire agreement between the parties as to the subject matter of this Agreement. There are no other agreements or understandings, written or oral, express or implied. This Agreement may be modified only by an instrument in writing signed by both parties.

19) EXPLANATION OF TERMS. EPOGY ACKNOWLEDGES THAT IT HAS READ AND UNDERSTOOD ALL OF THE TERMS AND PROVISIONS OF THIS AGREEMENT, AND THAT THEY ARE REASONABLY CLEAR.

20) ADVICE OF COUNSEL. EPOGY ACKNOWLEDGES THAT, PRIOR TO EXECUTING THIS AGREEMENT IT WAS INFORMED OF ITS RIGHTS TO SEEK ADVICE OF INDEPENDENT LEGAL COUNSEL, AND HAS HAD THE OPPORTUNITY TO SEEK THE ADVICE OF THE SAME.

21) Construction of Agreement. This agreement shall not be construed against any party by reason of the drafting or preparation hereof.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed and delivered in the United States by their duly authorized representatives.

Epogy Communications, Inc.

By: HChang
Name: Homer Chang
Title: President & CEO

Purchaser

By: J Nicholas Gross
Name: John Nicholas Gross
Attorney At Law

EXHIBIT A

LIST OF PATENTS/APPLICATIONS

1. U.S. Patent No. 5,781,788

2. U.S. Provisional Patent Application serial no. 60/358,928

3. Any and all patent applications (provisionals and/or non-provisionals) that are not yet drafted or filed, but which could be filed on the Intellectual Property.

JNG

EXHIBIT B

ASSIGNMENT

For good and valuable consideration, the receipt and sufficiency of which is here by acknowledged, Assignor hereby sells, assigns, transfers and conveys to John Nicholas Gross ("Purchaser"), its designees, successors, assigns, and legal representatives, Assignor's entire right, title, and interest in and to U.S. patent No. 5,781,788, provisional patent application no. 60/358,928, all non-provisional applications, divisions, continuations, and renewals thereof, all foreign patents which may be granted on any foreign applications corresponding thereto, all reissues and extensions thereof, all proceeds therefrom including but not limited to, all license royalties and/or damages and proceeds of infringement suits, and any and all causes of action for past, present, and future infringement of any of the above U.S. and foreign patents or relating to any inventions or discoveries described therein, including the right to collect damages for all such infringements and the right to sue on all such causes of action for their own use and benefit and the use and benefit of their successors, assigns, and legal representatives, each and every of the foregoing rights, titles, and interests herein assigned to be held and enjoyed by Purchaser, its successors, assigns, and legal representatives, as fully and entirely as the same would have been held and enjoyed by Assignor had this Assignment not been made.

IN TESTIMONY WHEREOF, Assignor has caused this Assignment to be duly executed in its name and behalf by affixing its hand and seal thereto by its designated officer, director, or agent, whose name and title appear below.

Executed at SUNNYVALE, CA this 15TH day of January 2003.

EPOGY COMMUNICATIONS, INC.

Signature: [signature]

Print Name/Title: PRESIDENT & CEO

JNG

ASSIGNMENT OF PATENT RIGHTS

For good and valuable consideration, the receipt of which is hereby acknowledged, J. Nicholas Gross having offices at 726 Duboce Avenue, San Francisco, CA 94117, ("*Assignor*"), does hereby sell, assign, transfer and convey unto Bellow Bellows LLC, a Delaware limited liability company, having an office at 171 Main Street, #271, Los Altos, California 94022 ("*Assignee*") or its designees, all of Assignor's right, title and interest in and to the patent applications and patents listed below, any patents, registrations, or certificates of invention issuing on any patent applications listed below, the inventions disclosed in any of the foregoing, any and all counterpart United States, international and foreign patents, applications and certificates of invention based upon or covering any portion of the foregoing, and all reissues, re-examinations, divisionals, renewals, extensions, provisionals, continuations and continuations-in-part of any of the foregoing (collectively "*Patent Rights*"):

Patent or Application No.	Country	Filing Date	Title and Inventor(s)
10/821,143	U.S.A.	April 7, 2004	Multi-Antenna Wireless Data Processing System; Shaolin Li
10/821,038	U.S.A.	April 7, 2004	Method of Operating Multi-Antenna Wireless Data Processing System; Shaolin Li
10/820,962	U.S.A.	April 7, 2004	System and Method for Achieving Timing Compatibility with Multi-Anenna Wireless Data Protocols; Shaolin Li
10/820,963	U.S.A.	April 7, 2004	Monitoring System Using Multi-Antenna Transceivers; Shaolin Li
10/820,961	U.S.A.	April 7, 2004	Single Chip Multi-Antenna Wireless Data Processor; Shaolin Li

Assignor represents, warrants and covenants that: (i) it is the sole owner, assignee and holder of record title to the Patent Rights identified above, (ii) to the best of its knowledge, it has obtained and properly recorded previously executed assignments for all patent applications and patents identified above as necessary to fully perfect its rights and title therein in accordance with governing law and regulations in each respective jurisdiction, and (iii) it has full power and authority

to make the present assignment. Assignor shall indemnify and hold harmless Assignee for any breach of the foregoing.

Assignor further agrees to and hereby does sell, assign, transfer and convey unto Assignee all rights: (i) in and to causes of action and enforcement rights for the Patent Rights including all rights to pursue damages, injunctive relief and other remedies for past and future infringement of the Patent Rights, and (ii) to apply in any or all countries of the world for patents, certificates of invention or other governmental grants for the Patent Rights, including without limitation under the Paris Convention for the Protection of Industrial Property, the International Patent Cooperation Treaty, or any other convention, treaty, agreement or understanding. Assignor also hereby authorizes the respective patent office or governmental agency in each jurisdiction to issue any and all patents or certificates of invention which may be granted upon any of the Patent Rights in the name of Assignee, as the assignee to the entire interest therein.

Assignor will, at the reasonable request of Assignee, do all things necessary, proper, or advisable, including without limitation the execution, acknowledgment and recordation of specific assignments, oaths, declarations and other documents on a country-by-country basis, to assist Assignee in obtaining, perfecting, sustaining, and/or enforcing the Patent Rights. Such assistance shall include providing, and obtaining from the respective inventors, prompt production of pertinent facts and documents, giving of testimony, execution of petitions, oaths, powers of attorney, specifications, declarations or other papers and other assistance reasonably necessary for filing patent applications, complying with any duty of disclosure, and conducting prosecution, reexamination, reissue, interference or other priority proceedings, opposition proceedings, cancellation proceedings, public use proceedings, infringement or other court actions and the like with respect to the Patent Rights.

The terms and conditions of this Assignment shall inure to the benefit of Assignee, its successors, assigns and other legal representatives, and shall be binding upon Assignor, its successor, assigns and other legal representatives.

IN WITNESS WHEREOF this Assignment of Patent Rights is executed at San Francisco, CA

on May 18, 2004.

ASSIGNOR

By: [signature]

Name: John Nicholas Goss

Title: Owner

(Signature MUST be notarized)

CALIFORNIA ALL-PURPOSE ACKNOWLEDGMENT

State of California
County of San Francisco } ss.

On May 18th 2004 (Date) before me, Aaron Craig Jacobson-Sanker, Notary Public, (Name and Title of Officer (e.g., "Jane Doe, Notary Public"))
personally appeared John Nicholas Gross, (Name(s) of Signer(s))

☐ personally known to me
☒ proved to me on the basis of satisfactory evidence

to be the person(~~s~~) whose name(~~s~~) is/~~are~~ subscribed to the within instrument and acknowledged to me that he/~~she/they~~ executed the same in his/~~her/their~~ authorized capacity(ies), and that by his/~~her/their~~ signature(~~s~~) on the instrument the person(~~s~~), or the entity upon behalf of which the person(~~s~~) acted, executed the instrument.

AARON CRAIG JACOBSON-SANKER
Comm. #1354586
NOTARY PUBLIC-CALIFORNIA
Santa Cruz County
My Comm. Expires May 2, 2006

WITNESS my hand and official seal.

Signature of Notary Public

OPTIONAL

Though the information below is not required by law, it may prove valuable to persons relying on the document and could prevent fraudulent removal and reattachment of this form to another document.

Description of Attached Document

Title or Type of Document: ____________________

Document Date: ____________________ Number of Pages: __________

Signer(s) Other Than Named Above: ____________________

Capacity(ies) Claimed by Signer

Signer's Name: ____________________

☐ Individual
☐ Corporate Officer — Title(s): ____________________
☐ Partner — ☐ Limited ☐ General
☐ Attorney-in-Fact
☐ Trustee
☐ Guardian or Conservator
☐ Other: ____________________

Signer Is Representing: ____________________

RIGHT THUMBPRINT OF SIGNER
Top of thumb here

EXHIBIT 1

DECLARATION BY J. NICHOLAS GROSS IN RE: APPLICATION NO. 10/821,143

1. The recitation below is intended solely for the purpose of assisting the application owner, Bellows Bellows LLC, to establish an appropriate chain of title in application numbers 10/820,961, 10/820,962,10/820,963,10/821,038 and 10/821,143 ("Bellows Bellows Applications"). The facts and discussion below are provided without waiver or prejudice to maintain attorney client privilege with respect to substantive matters involving these applications that are unrelated to the issue of ownership.

2. The above referenced non-provisional applications 10/820,961, 10/820,962, 10/820,963, 10/821,038 and 10/821,143 are all based on a single provisional application 60/461,170 filed April 7, 2003. A copy of this provisional application is attached as Exhibit A.

3. My practice is based in San Francisco, California. I was contacted by and met with Mr. Homer Chang, President of Epogy, Inc., in October 2001 to consult on IP matters for such company, which at the time was located in Santa Clara, California. Mr. Chang was referred to me by Mr. Daniel Chen and Mr. Peter Courture, both of whom were also on the board of directors of Epogy.

4. Mr. Chang informed me that Epogy was designing a new WiFi ASIC device for use in a high speed wireless access point. As part of such efforts he specifically expressed the desire for Epogy to file for patent protection in connection with certain technologies invented by its employee as part of such design efforts, including on various aspects of multiple in multiple out (MIMO) signal processing.

5. After our meeting, Mr. Chang sent me some background materials during October - December 2001 on the developments achieved to date at Epogy. These included the attached materials at Exhibit B. As can be seen from a simple side by side comparison, these same materials form part of the provisional application referred to above and the disclosure for the related cases deriving priority therefrom, including the cases noted above.

6. Mr. Chang specifically referred to Dr. Shaolin Li as the inventor of the technologies embodied in the materials sent to me, and instructed me to deal with Dr. Li for any patent filings. He further made it very clear that Dr. Li was an employee of Epogy, and that such work was done on behalf of the company.

7. As also can be seen, many of these materials provided to me by Mr.Chang at that time in fact bear the name of Dr. Shaolin Li and are dated contemporaneously with our discussions. I was told by Mr. Chang that Dr. Li was the head of the design team for the ASIC project, and that the company intended to file one or more patent applications on various aspects of Dr. Li's inventions conceived as part of his work on behalf of Epogy.

8. Accordingly, as of December 2001, Mr. Chang was the sole source of the materials which are embodied in the Bellows Bellows LLC applications. All communications and meetings occurred at Epogy's facilities during normal business hours. At no time did Mr. Chang ever express to me that these materials belonged to Dr. Li, or that he was working on Dr. Li's behalf.

9. In January and February of 2002, I met in person with Dr. Li, Mr. Chang, and other employees /officers of Epogy on one or more occasions in person to discuss the nature of the innovations at Epogy, and the potential for filing patent applications on the same. Dr. Li confirmed the substance of what had been expressed to me earlier by Mr. Chang, namely, that he was the author of the technical materials given to me, that such materials were created during the course of his work on the MIMO ASIC project, and that the company expected to file patent applications to cover portions of such work.

10. As part of the discourse and follow-up from these meetings, Dr. Li was specifically instructed to assist me with the process of drafting/filing a patent application to cover the inventions he conceived and/or reduced to practice at Epogy in connection with the MIMO ASIC. All of these communications and meetings occurred either at Epogy's place of business, using Epogy telephones, fax machines and email accounts. At no time did Dr. Li communicate with me in a capacity outside the scope of his work as an employee.

11. During the course of communications from January to February 2002, the subject of assignment of rights to Epogy for the inventions embodied in the to-be-filed applications was also brought up. Mr. Chang and other Epogy personnel made it clear that such applications belonged to Epogy, and that Dr. Li would sign an assignment form to allow for perfection of rights in the USPTO. Dr. Li was present during these conversations, and at no time did he dispute such claim of ownership, or suggest in any manner that the inventions in such materials did not belong to Epogy.

12. After meeting with Dr. Li on a few occasions, I further asked him to help prepare a draft of a preliminary disclosure which could serve as a template for any filed patent application. At the time, the intent was to file for a full, non-provisional application. In response to this request Dr. Li provided me with the materials noted in <u>Exhibit C</u> which as can be seen, bear Epogy's company letterhead and a confidential designation. Again, as can be seen from a simple side by side comparison, these same materials form part of the provisional application referred to above and the disclosure for the related cases deriving priority therefrom, including the cases noted above.

13. Accordingly, at all relevant times Dr. Li represented and confirmed that such disclosures contained materials belonging solely to Epogy and not some other party.

14. I have attached a copy of an invoice sent to Epogy which corroborates the dates and scope of activities performed and as described above. See <u>Exhibit D.</u> These

confirm that the relevant services were rendered by me in the period described above, including during the periods when Dr. Li was an employee of Epogy.

15. Sometime in the summer of 2002 I was informed by Epogy that they no longer had funding, and would have to defer any filings until such time as they secured other financial resources. Notably, Dr. Li's employment was not terminated with Epogy until after he had authored and communicated the materials which form the basis of the provisional application and the Bellows Bellows LLC applications noted above.

16. The provisional application 60/461,170 (Exhibit A) was prepared personally by me in April 2003 based entirely on communications and materials given to me Mr. Chang and/or Dr. Li during the time period of October 2001 to April 2002, during which time the latter Li was employed at Epogy.

17. The aforementioned Bellows Bellows Applications (10/820,961, 10/820,962, 10/820,963, 10/821,038 and 10/821,143) were prepared personally by me in April 2004, based solely on the provisional application (60/461,170 (Exhibit A)) communications and materials given to me, Mr. Chang and/or Dr. Li during the time period of October 2001 to April 2002, during which time the latter Li was employed at Epogy.

18. Because I wrote these applications, I can verify that any and all patentable inventions presented in the present application 10/821,143 are derived directly from the disclosures and materials given to me by Dr. Li on behalf of Epogy, and which were generated during the latter months of 2001 and early part of 2002. Accordingly, and as detailed above, such inventions were conceived and/or reduced to practice: (1) during a time Dr. Li was an employee of Epogy; (2) based on work he performed on Epogy's behalf and not some other capacity; (3) while he was under contractual obligation to assign any invention rights.

19. Consequently in December 2002, Epogy owned all rights and a clear title in the present application, by way of the obligations agreed to by Dr. Lin in writing for his employment agreement. His understanding and acceptance of such obligations was further confirmed by his actions and consent in January 2002 during our meetings. The other circumstantial evidence above including the communication and treatment of the Epogy confidential information by Mr. Chang and Dr. Li, leaves no reasonable doubt on the issue of ownership.

20. In January 2003, I purchased all such rights, and other existing and remaining intellectual property assets owned by Epogy. A redacted copy of such agreement is attached as Exhibit E.

21. In July 2004, I sold all rights in the present applications to Bellows Bellows LLC. A redacted copy of such agreement is attached as Exhibit F.

22. Based on the above, I submit there is more than sufficient and conclusive documentary and testimonial evidence to support a continuous chain of ownership title to the Applicant for the aforementioned Bellows Bellows Applications.

23. I declare under penalty of perjury that the foregoing is true and accurate to the best of my information, knowledge and belief.

Dated: 1/10/05

J. Nicholas Gross
726 Duboce Ave
San Francisco, CA 94117
Reg. No. 34175

EXHIBIT 2

epogy
communications

EPOGY COMMUNICATIONS, INC.
EMPLOYMENT, CONFIDENTIAL INFORMATION AND INVENTION ASSIGNMENT AGREEMENT

As a condition of my employment with Epogy Communications, Inc., its subsidiaries, affiliates, successors or assigns (collectively, the "Company"), and in consideration of my employment with the Company and my receipt of the compensation now and hereafter paid to me by the Company, I hereby acknowledge and agree that:

1. At-Will Employment. I UNDERSTAND AND ACKNOWLEDGE THAT MY EMPLOYMENT WITH THE COMPANY IS FOR NO SPECIFIC TERM AND CONSTITUTES "AT-WILL" EMPLOYMENT. I ALSO UNDERSTAND THAT ANY REPRESENTATION TO THE CONTRARY IS UNAUTHORIZED, INVALID, AND CANNOT BE RELIED UPON BY ME UNLESS OBTAINED IN WRITING AND SIGNED BY THE CHIEF EXECUTIVE OFFICER OF THE COMPANY. I FURTHER UNDERSTAND AND ACKNOWLEDGE THAT I MAY BE TERMINATED BY THE COMPANY AT ANY TIME, WITH OR WITHOUT GOOD CAUSE OR FOR ANY OR NO CAUSE, AT THE OPTION OF EITHER THE COMPANY OR MYSELF, WITH OR WITHOUT NOTICE. DURING MY PERIOD OF EMPLOYMENT BY THE COMPANY, I WILL DEVOTE MY BEST EFFORTS TO THE INTERESTS OF THE COMPANY AND WILL NOT ENGAGE IN OTHER EMPLOYMENT OR IN ANY BUSINESS ACTIVITIES DETERMINED BY THE COMPANY TO BE DETRIMENTAL TO THE BEST INTERESTS OF THE COMPANY WITHOUT THE PRIOR WRITTEN CONSENT OF THE CHIEF EXECUTIVE OFFICER OF THE COMPANY. I ALSO AGREE TO PERFORM FOR THE COMPANY SUCH DUTIES AS MAY BE DESIGNATED BY THE COMPANY FROM TIME TO TIME .

2. Prior Work. All previous work done by me for the Company relating in any way to the conception, design, development or support of products for the Company is the property of the Company.

3. Proprietary Information. My employment creates a relationship of confidence and trust between the Company and me with respect to any information:

(a) Applicable to the business of the Company; or

(b) Applicable to the business of any client or customer of the Company, which may be made known to me by the Company or by any client or customer of the Company, or learned by me in such context during the period of my employment.

All of such information has commercial value in the business in which Company is engaged and is hereinafter called "Company Proprietary Information." By way of illustration, but not limitation, Company Proprietary Information includes any and all technical and non-technical information including patent, copyright, trade secret, and proprietary information, techniques, sketches, drawings, models, inventions, know-how, processes, apparatus,

equipment, algorithms, software programs, software source documents, and formulae related to the current, future and proposed products and services of Company, and includes, without limitation, its respective information concerning research, experimental work, development, design details and specifications, engineering, financial information, procurement requirements, purchasing manufacturing, customer lists, business forecasts, sales and merchandising and marketing plans and information. "Third Party Proprietary Information" means proprietary or confidential information of any third party who may disclose such information to Company or me in the course of Company's business. Company Proprietary Information and Third Party Proprietary Information are hereinafter collectively referred to as "Proprietary Information."

4. Nondisclosure of Proprietary Information. All Proprietary Information is the sole property of the Company, its assigns, and its customers and the Company, its assigns and its customers shall be the sole owner of all patents, copyrights, maskworks, trade secrets and other rights in connection therewith. I hereby assign to the Company any rights I may have or acquire in Company Proprietary Information. At all times, both during my employment by the Company and after its termination, I will keep in confidence and trust all Proprietary Information, and I will not use or disclose any Proprietary Information or anything directly relating to it without the written consent of the Company, except as may be necessary in the ordinary course of performing my duties as an employee of the Company. Notwithstanding the foregoing, it is understood that, at all such times, I am free to use information which is generally known in the trade or industry not as a result of a breach of this Agreement and my own skill, knowledge, know-how and experience to whatever extent and in whatever way I wish provided that such use does not result in the disclosure of Company Proprietary Information or the direct or indirect infringement of any intellectual property right now owned or hereafter acquired by the Company.

5. Return of Materials. Upon termination of my employment or at the request of the Company before termination, I will deliver to the Company all written and tangible material in my possession incorporating the Proprietary Information or otherwise relating to the Company's business. In the event of my termination of employment, I agree to sign and deliver the "Termination Certification " attached hereto as Exhibit C.

6. Inventions. As used in this Agreement, the term "Inventions" means any and all new or useful art, discovery, improvement, technical development, or invention whether or not patentable, and all related know-how, designs, maskworks, trademarks, formulae, processes, manufacturing techniques, trade secrets, ideas, artwork, software or other copyrightable or patentable works.

7. Disclosure of Prior Inventions. I have identified on Exhibit A ("Prior Inventions") attached hereto all Inventions relating in any way to the Company's business or demonstrably anticipated research and development which were made by me prior to my employment with the Company ("Prior Inventions"), and I represent that such list is complete. I represent that I have no rights in any such Inventions other than those Prior Inventions specified in Exhibit A ("Prior Inventions"). If there is no such list on Exhibit A ("Prior Inventions"), I represent that I have made no such Prior Inventions at the time of signing this Agreement.

8. Ownership of Company Inventions; License of Prior Inventions. I hereby assign and agree to assign to the Company or its designee, my entire right, title, and interest in and to all Inventions ("Company Inventions") and any associated intellectual property rights which I may solely or jointly conceive, develop or reduce to practice during the period of my

employment with the Company (a) which relate at the time of conception or reduction to practice of the invention to the Company's business or actual or demonstrably anticipated research or development, or (b) which were developed on any amount of the Company's time or with the use of any of the Company's equipment, supplies, facilities or trade secret information, or (c) which resulted from any work I performed for the Company. I hereby agree promptly to disclose and describe to the Company any and all potentially patentable Company Inventions. I agree to grant the Company or its designees a royalty free, irrevocable, worldwide license (with rights to sublicense through multiple tiers of distribution) to practice all applicable patent, copyright and other intellectual property rights relating to any Prior Inventions which I incorporate, or permit to be incorporated, in any Company Inventions without the prior written consent of the Company. Notwithstanding the foregoing, I agree that I will not incorporate, or permit to be incorporated, such Prior Inventions in any Company Inventions without Company's prior written consent.

9. <u>Name & Likeness Rights, Etc.</u> I hereby authorize the Company to use, reuse, and to grant others the right to use and reuse, my name, photograph, likeness and biographical information in a manner that is similar to the manner in which such items are typically used in the computer industry.

10. <u>Assignment of Other Rights</u>. In addition to the foregoing assignment of Inventions to the Company, I hereby irrevocably transfer and assign to the Company: (a) all worldwide patents, patent applications, copyrights, mask works, trade secrets and other intellectual property rights in any Company Invention; and (b) any and all "Moral Rights" (as defined below) that I may have in or with respect to any Company Invention. I also hereby forever waive and agree never to assert any and all Moral Rights I may have in or with respect to any Company Invention, even after termination of my work on behalf of the Company. "Moral Rights" mean any rights to claim authorship of an invention to object to or prevent the modification of any invention, or to withdraw from circulation or control the publication or distribution of any invention, and any similar right, existing under judicial or statutory law of any country in the world, or under any treaty, regardless of whether or not such right is denominated or generally referred to as a "moral right."

11. <u>Cooperation in Perfecting Rights to Inventions</u>.

(a) I agree to perform, during and after my employment, all acts deemed necessary or desirable by the Company to permit and assist it, at its expense, in obtaining and enforcing the full benefits, enjoyment, rights and title throughout the world in the Inventions hereby assigned to the Company. Such acts may include, but are not limited to, execution of documents and assistance or cooperation in the registration and enforcement of applicable patents, copyrights, maskworks or other legal proceedings.

(b) In the event that the Company is unable after reasonable efforts to secure my signature to any document required to apply for or execute any patent, copyright, maskwork or other applications with respect to any Company Inventions (including improvements, renewals, extensions, continuations, divisions or continuations in part thereof), I hereby irrevocably designate and appoint the Company and its duly authorized officers and agents as my agents and attorneys-in-fact to act for and on my behalf to execute and file any such application and to do all other lawfully permitted acts to further the prosecution and

issuance of patents, copyrights, maskworks or other rights thereon with the same legal force and effect as if executed by me.

12. No Violation of Rights of Third Parties. My performance of all the terms of this Agreement and as an employee of the Company does not and will not breach any agreement to keep in confidence proprietary information, knowledge or data acquired by me prior to my employment with the Company, and I will not disclose to the Company, or induce the Company to use, any confidential or proprietary information or material belonging to any previous employer or others. I am not a party to any other agreement which will interfere with my full compliance with this Agreement. I agree not to enter into any agreement, whether written or oral, in conflict with the provisions of this Agreement.

13. Survival. This Agreement (a) shall survive my employment by the Company, (b) does not in any way restrict my right or the right of the Company to terminate my employment at any time, for any reason or for no reason, (c) inures to the benefit of successors and assigns of the Company, and (d) is binding upon my heirs and legal representatives.

14. Nonassignable Inventions. This Agreement does not apply to an Invention which qualifies fully as a nonassignable invention under the provisions of Section 2870 of the California Labor Code. I have reviewed the notification in Exhibit B ("Limited Exclusion Notification") and agree that my signature acknowledges receipt of the notification.

15. Duty Not to Compete. During my employment, I will not, without the Company's express written consent, undertake planning for or organization of any business activity competitive with the Company's business, or combine or act in concert with employees or representatives of the Company for the purposes of organizing any such competitive business activity. In addition, during my employment, I agree that I will not engage in any employment or business, or invest in or assist in any manner any business, which directly or indirectly competes with the business or future plans of the Company, except for less than a 5% investment in a public company.

16. Non-Solicitation. During the term of my employment with the Company and for a period of two years thereafter, I will not directly or indirectly solicit or encourage any employees, consultants, suppliers, or customers of the Company to terminate or alter their relationship with the Company or cause others to do so.

17. Notification of New Employer. I hereby authorize the Company to notify my actual or future employers of the terms of this Agreement and my responsibilities hereunder.

18. Injunctive Relief. A breach of any of the promises or agreements contained herein will result in irreparable and continuing damage to the Company for which there will be no adequate remedy at law, and the Company shall be entitled to injunctive relief and/or a decree for specific performance, and such other relief as may be proper (including monetary damages if appropriate).

19. Notices. Any notice required or permitted by this Agreement shall be in writing and shall be delivered as follows with notice deemed given as indicated: (i) by personal delivery when delivered personally; (ii) by overnight courier upon written verification of receipt; (iii) by telecopy or facsimile transmission upon acknowledgment of receipt of electronic transmission; (iv) by certified or registered mail, return receipt requested, upon verification of

receipt; or (v) by electronic mail to an officer of the Company upon receipt of a return electronic mail from such officer acknowledging my electronic mail. Notice shall be sent to the addresses set forth above or such other address as either party may specify in writing.

20. Governing Law. This Agreement shall be governed in all respects by the laws of the United States of America and by the laws of the State of California, as such laws are applied to agreements entered into and to be performed entirely within California between California residents.

21. Severability. Should any provisions of this Agreement be held by a court of law to be illegal, invalid or unenforceable, the legality, validity and enforceability of the remaining provisions of this Agreement shall not be affected or impaired thereby.

22. Waiver. The waiver by the Company of a breach of any provision of this Agreement by me shall not operate or be construed as a waiver of any other or subsequent breach by me.

23. Assignment by Company. The term "Company" shall mean Epogy Comminations, Inc, a California corporation (or any subsidiary thereof). The Company shall have the right to assign this Agreement to its successors and assigns, and all covenants and agreements hereunder shall inure to the benefit of and be enforceable by said successors or assigns (or any subsidiary thereof).

24. Consulting. For purposes of this Agreement the term "employment" shall also mean any period of consultancy or otherwise contracting with the Company.

25. Entire Agreement. This Agreement represents my entire understanding with the Company with respect to the subject matter of this Agreement and supersedes all previous understandings, written or oral. This Agreement may be amended or modified only with the written consent of both me and the Company. No oral waiver, amendment or modification shall be effective under any circumstances whatsoever.

26. Conflict of Interest Guidelines. I agree to diligently adhere to the Conflict of Interest Guidelines attached as Exhibit D hereto.

27. Consent to Personal Jurisdiction. I hereby expressly consent to the personal jurisdiction of the Santa Clara County Superior Court and the United States Federal Court for the Northern District of California for any lawsuit filed their against me by the Company arising from or relating to this Agreement.

28. Arbitration and Equitable Relief.

(a) Arbitration. I AGREE THAT ANY DISPUTE OR CONTROVERSY ARISING OUT OF, RELATING TO, OR CONCERNING ANY INTERPRETATION, CONSTRUCTION, PERFORMANCE OR BREACH OF THIS AGREEMENT, SHALL BE SETTLED BY ARBITRATION TO BE HELD IN SANTA CLARA COUNTY, CALIFORNIA, IN ACCORDANCE WITH THE EMPLOYMENT DISPUTE RESOLUTION RULES OF JAMS/ENDISPUTE THEN IN EFFECT. THE ARBITRATOR MAY GRANT INJUNCTIONS OR OTHER RELIEF IN SUCH DISPUTE OR CONTROVERSY. THE DECISION OF THE ARBITRATOR SHALL BE FINAL, CONCLUSIVE AND BINDING ON THE PARTIES TO THE

ARBITRATION. JUDGMENT MAY BE ENTERED ON THE ARBITRATOR'S DECISION IN ANY COURT HAVING JURISDICTION. EMPLOYEE SHALL PAY A FILING FEE OF TWO HUNDRED DOLLARS AND THE COMPANY SHALL PAY THE REMAINING ARBITRATION COSTS AND EXPENSES. EACH OF US SHALL SEPARATELY PAY OUR COUNSEL FEES AND EXPENSES.

(b) THE PARTIES MAY APPLY TO THE SANTA CLARA COUNTY SUPERIOR COURT AND THE UNITED STATES FEDERAL COURT FOR THE NORTHERN DISTRICT OF CALIFORNIA FOR A TEMPORARY RESTRAINING ORDER, PRELIMINARY INJUNCTION, OR OTHER INTERIM OR CONSERVATORY RELIEF, AS NECESSARY, WITHOUT BREACH OF THIS ARBITRATION AGREEMENT AND WITHOUT ABRIDGEMENT OF THE POWERS OF THE ARBITRATOR.

(c) I UNDERSTAND THAT NOTHING IN SECTION 10 MODIFIES MY AT-WILL STATUS. EITHER THE COMPANY OR I CAN TERMINATE THE EMPLOYMENT RELATIONSHIP AT ANY TIME, WITH OR WITHOUT CAUSE.

I UNDERSTAND THAT THIS ARBITRATION CLAUSE CONSTITUTES A WAIVER OF MY RIGHT TO A JURY TRIAL AND RELATES TO THE RESOLUTION OF ALL DISPUTES RELATING TO ALL ASPECTS OF THE EMPLOYER/EMPLOYEE RELATIONSHIP (EXCEPT AS PROVIDED IN SECTION 10(b) ABOVE), INCLUDING, BUT NOT LIMITED TO, THE FOLLOWING CLAIMS:

i. ANY AND ALL CLAIMS FOR WRONGFUL DISCHARGE OF EMPLOYMENT; BREACH OF CONTRACT, BOTH EXPRESS AND IMPLIED; BREACH OF THE COVENANT OF GOOD FAITH AND FAIR DEALING, BOTH EXPRESS AND IMPLIED; NEGLIGENT OR INTENTIONAL INFLICTION OF EMOTIONAL DISTRESS; NEGLIGENT OR INTENTIONAL MISREPRESENTATION; NEGLIGENT OR INTENTIONAL INTERFERENCE WITH CONTRACT OR PROSPECTIVE ECONOMIC ADVANTAGE; AND DEFAMATION;

ii. ANY AND ALL CLAIMS FOR VIOLATION OF ANY FEDERAL, STATE OR MUNICIPAL STATUTE, INCLUDING, BUT NOT LIMITED TO, TITLE VII OF THE CIVIL RIGHTS ACT OF 1964, THE CIVIL RIGHTS ACT OF 1991, THE AGE DISCRIMINATION IN EMPLOYMENT ACT OF 1967, THE AMERICANS WITH DISABILITIES ACT OF 1990, THE FAIR LABOR STANDARDS ACT, THE CALIFORNIA FAIR EMPLOYMENT AND HOUSING ACT, AND LABOR CODE SECTION 201, *et seq;*

iii. ANY AND ALL CLAIMS ARISING OUT OF ANY OTHER LAWS AND REGULATIONS RELATING TO EMPLOYMENT OR EMPLOYMENT DISCRIMINATION.

(d) Consideration. I UNDERSTAND THAT EACH PARTY'S PROMISE TO RESOLVE CLAIMS BY ARBITRATION IN ACCORDANCE WITH THE PROVISIONS OF THIS AGREEMENT, RATHER THAN THROUGH THE COURTS, IS CONSIDERATION FOR OTHER PARTY'S LIKE PROMISE. I FURTHER UNDERSTAND THAT I AM OFFERED EMPLOYMENT IN CONSIDERATION OF MY PROMISE TO ARBITRATE CLAIMS.

29. I acknowledge and agree to each of the following terms:

(a) I am executing this Agreement voluntarily and without any duress or undue influence by the Company or anyone else;

(b) I have carefully read this Agreement. I have asked any questions needed for me to understand the terms, consequences and binding effect of this Agreement and fully understand them; and

(c) I sought the advance of an attorney of my choice if I wanted to before signing this Agreement.

"Company"	"Employee"
EPOGY COMMUNICATIONS, INC.	
By: H Chang	By: Li Shaoli
Name: HOMER CHANG	Name: Shaolin Li
Title: CEO	
Date: 9/18/00	Date: 9/18/00

Exhibit A

PRIOR INVENTIONS

Exhibit B

LIMITED EXCLUSION NOTIFICATION

THIS IS TO NOTIFY you in accordance with Section 2872 of the California Labor Code that the foregoing Agreement between you and the Company does not require you to assign or offer to assign to the Company any invention that you developed entirely on your own time without using the Company's equipment, supplies, facilities or trade secret information except for those inventions that either:

(1) Relate at the time of conception or reduction to practice of the invention to the Company's business, or actual or demonstrably anticipated research or development of the Company; or

(2) Result from any work performed by you for the Company.

To the extent a provision in the foregoing Agreement purports to require you to assign an invention otherwise excluded from the preceding paragraph, the provision is against the public policy of this state and is unenforceable.

This limited exclusion does not apply to any patent or invention covered by a contract between the Company and the United States or any of its agencies requiring full title to such patent or invention to be in the United States.

I ACKNOWLEDGE RECEIPT of a copy of this notification.

By: Li Shaoli

Name: Shaolin Li
(Printed Name of Employee)

Date: 9/18/00

Witnessed by:

H Chang

HOMER CHANG
(Printed Name of Representative)

Exhibit C

EPOGY COMMUNICATIONS, INC.

TERMINATION CERTIFICATION

This is to certify that I do not have in my possession, nor have I failed to return, any devices, records, data, notes, reports, proposals, lists, correspondence, specifications, drawings, blueprints, sketches, materials, equipment, other documents or property, or reproductions of any aforementioned items belonging to Epogy Comminations, Inc., its subsidiaries, affiliates, successors or assigns (together, the "Company").

I further certify that I have complied with all the terms of the Company's Confidential Information, Invention Assignment and Terms of Employment Agreement signed by me, including the reporting of any inventions and original works of authorship (as defined therein), conceived or made by me (solely or jointly with others) covered by that agreement.

I further agree that, in compliance with the Confidential Information, Invention Assignment and Terms of Employment Agreement, I will preserve as confidential all trade secrets, confidential knowledge, data or other proprietary information relating to products, processes, know-how, designs, formulas, developmental or experimental work, computer programs, data bases, other original works of authorship, customer lists, business plans, financial information or other subject matter pertaining to any business of the Company or any of its employees, clients, consultants or licensees.

I further agree that for twelve (24) months from this date, I will not hire any employees of the Company and I will not solicit, induce, recruit or encourage any of the Company's employees to leave their employment.

Date: ____________

____
(Employee's Signature)

____
(Type/Print Employee's Name)

Exhibit D

EPOGY COMMUNICATIONS, INC.

CONFLICT OF INTEREST GUIDELINES

It is the policy of Epogy Communications, Inc. to conduct its affairs in strict compliance with the letter and spirit of the law and to adhere to the highest principles of business ethics. Accordingly, all officers, employees and independent contractors must avoid activities which are in conflict, or give the appearance of being in conflict, with these principles and with the interests of the Company. The following are potentially compromising situations which must be avoided. Any exceptions must be reported to the President and written approval for continuation must be obtained.

1. Revealing confidential information to outsiders or misusing confidential information. Unauthorized divulging of information is a violation of this policy whether or not for personal gain and whether or not harm to the Company is intended. (The Confidential Information, Invention Assignment and terms of Employment Agreement elaborates on this principle and is a binding agreement.)

2. Accepting or offering substantial gifts, excessive entertainment, favors or payments which may be deemed or constitute undue influence or otherwise be improper or embarrassing to the Company.

3. Participating in civic or professional organizations that might involve divulging confidential information of the Company.

4. Initiating or approving personnel actions affecting reward or punishment of employees or applicants where there is a family relationship or is or appears to be a personal or social involvement.

5. Initiating or approving any form of personal or social harassment of employees.

6. Investing or holding outside directorship in suppliers, customers, or competing companies, including financial speculations, where such investment or directorship might influence in any manner a decision or course of action of the Company.

7. Borrowing from or lending to employees, customers or suppliers.

8. Acquiring real estate of interest to the Company.

9. Improperly using or disclosing to the Company any proprietary information or trade secrets of any former or concurrent employer or other person or entity with whom obligations of confidentiality exist.

10. Unlawfully discussing prices, costs, customers, sales or markets with competing companies or their employees.

11. Making any unlawful agreement with distributors with respect to prices.

12. Improperly using or authorizing the use of any inventions which are the subject of patent claims of any other person or entity.

13. Engaging in any conduct which is not in the best interest of the Company.

Each officer, employee and independent contractor must take every necessary action to ensure compliance with these guidelines and to bring problem areas to the attention of higher management for review. Violations of this conflict of interest policy may result in discharge without warning.

3. Vacation. You will be entitled to 10 days paid vacation per year, pro-rated for the remainder of this calendar year, in accordance with the Company's vacation policy.

(E) As required by law according to the Immigration Reform and Control Act of 1986, this offer and your subsequent employment are contingent upon you completing Form I-9 and producing proof that you are legally entitled to work in the United States. You employment with the Company will be "at will" and may be terminated by you or the Company at any time, with or without cause. You acceptance of this offer and commencement of employment with the Company are is further contingent upon your execution of a Epogy Communications, Inc. Employment, Confidential Information and Invention Assignment Agreement which will be provided to you for your review and signature prior to your first day of employment.

(F) You have told the Company that your signing of this letter, the issuance of the stock options to you, and your commencement of employment with the Company do not violate any agreement you have with your current employer; your signature confirms this representation.

To indicate your acceptance of the Company's offer, please sign and date this letter in the space provided below and return it to me, along with a signed and dated copy of the Epogy Communications, Inc. Employment, Confidential Information and Invention Assignment Agreement which will be provided to you. This letter, together with the Epogy Communications, Inc. Employment, Confidential Information and Invention Assignment Agreement, sets forth the terms of your employment with the Company and supersedes any prior representations or agreements, whether written or oral. This letter may not be modified or amended except by a written agreement, signed by the Company and you.

We look forward to working with you at Epogy Communications, Inc.

Sincerely,

EPOGY COMMUNICATION INC.

HChang

Homer Chang, Chairman and
Chief Executive Officer

APPROVED AND AGREED TO:

Employee: L. Shaoli

Dated: 9/18/00